Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Surface Water Specialist Study

Report Prepared for

Sierra Rutile Limited

Sierra Rutile Limited

Report Number: 515234/ D1 Surface Water

Report Prepared by

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Sierra Rutile Project Area 1 – Environmental, Social and Health Impact Assessment: Surface Water Specialist Study

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Executive Summary

Sierra Rutile Limited (SRL) is an active mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon concentrates. The SRL operation has an existing Environmental Licence (EPA-SL030) and had previously undertaken two Environmental and Social Impact Assessment (ESIA) studies, one in 2001 and an amendment in 2012. At the time of the two Assessments, the primary mining process employed was dredge mining. However, in or around 2013, SRL commenced with supplementary surface / opencast mining operations to optimally extract the ore. With the commissioning of a second dry mining operation in 2016, SRL anticipate that, over time, dredge mining will cease as the primary mining method employed at Area 1.

SRL appointed SRK Consulting (South Africa) (Pty) Ltd (SRK) to undertake an Environmental, Social and Health Impact Assessment (ESHIA). This surface water study will form part of the ESHIA update (to existing EMPs) and the application for further opencast mining.

A surface water study is required to assimilate and report on the available data as well as the data collected during the project. An impact assessment and the management measures are needed to ensure that the establishment of the future mining areas will have a minimal impact on the water resources in and around the mining area.

The study describes the surface water baseline for the project for both quantity and quality. Furthermore, identify potential impact(s) caused by the expansion of the mining area and provide mitigation measures.

The work program includes the following activities:

- Collect water quality samples as stated in the Water Quality Monitoring Protocol document generated by SRK Consulting;
- Assemble relevant water resources, climatic, topographic, water quality and water quantity data;
- Use the assimilated data to proceed with:
    - Water Resource modelling to understand the monthly flows with the dams in place as well with the dams removed;
    - Determine the peak flows for various catchments that were identified;
    - Determine the 1:50 and 1:100-year Return Period floodlines for various river reaches;
    - Develop a conceptual Surface Water Management Plan (SWMP) around the existing and proposed infrastructure;
    - Compile a water balance for the site;
    - Use the water quality data collected to compare it against local water quality guidelines; and
    - Use the water level data for the various impoundments to show the trends and risks with dam levels recorded.
- Assess the hydrological impacts of the project;
- Tabulate all impacts, assign severity and risk rankings to each;
- Derive management measures to reduce impacts to acceptable levels; and
- Compile a report detailing the surface water assessment, the impact assessment and the management measures.

A summary of the results are as follows:

- The average rainfall for the Mineral Separation Plant (MSP) site is estimated to be around 2 800 mm/year. The wet season typically begins in May and ends in November with the highest average monthly rainfall reading of 651 mm (in August). The dry season, beginning in December and ending in April, is characterised by low rainfall. The average rainfall during the dry season varies from a minimum of 6 mm in January to a maximum of 97 mm in April;
- The impact of flooding can be mitigated by diverting the natural runoff away from the disturbed areas in a practical method outlined in the main report;
- There is a generally low pH, and little mineral content for buffering, that there can be an expectation of mineralisation and solubilisation of some metals, including aluminium from the resident soils, which may occur naturally, and not necessarily directly caused by SRL operations. Whilst mining would usually be expected to impact surface water quality by disturbing the soils and ore bodies, on-going monitoring will better assist to assess natural influences on water quality versus mine related influences;
- It should be noted that a low pH of surface water samples with low mineral and salt content may be a natural reflection of the dissolution of carbon dioxide from the atmosphere, respiration of aquatic life forms and dissolution of natural soil humic acids etc. It does not necessarily infer that there is a direct detrimental impact of mining activities where not supported by significant changes in the ionic balance of the water;
- A slightly acidic pH of surface water samples similarly does not imply that the water quality is not fit-for-use, for domestic use or supporting aquatic life, particularly associated with weak acids such as carbonic acid from carbon dioxide. Future water quality monitoring should consider the specific concentration limits recommended in guidelines for water uses, but should also consider the context of the water use, supported by aquatic biomonitoring, and understanding of the practical risk that the water quality parameters may pose, if any, to human health and the environment, in the context of the SRL operations;
- Mogbwemo Domestic Pond, although used by the local community as a domestic source of water, did not meet the drinking water quality guidelines in July and August due to the low pH (4.2 – 4.7) and elevated aluminium concentrations. The quality improved slightly in October 2017 with a drop in aluminium concentrations to within drinking water quality guideline limits. The pH was not measured in October 2017;
- The water discharging from the MSP tailings, through to the Mogbwemo Dredge Pond is impacted by the mining activities. The pH is below the legislative limits and aluminium concentrations exceed the drinking water standard limits. The concentration of determinants appears to decrease at surface water locations further away from the MSP areas;
- The impact from mining activities is far less obvious downstream of Bamba/Belebu Pond, as only slightly acidic (pH 5.8) conditions were noted in August 2017 at SW14. This is expected as there is no active mining occurring in this catchment;
- At the old mining areas of Pejebu, the dam and dredge pond water quality is comparable to the background water quality, except the acidity that exceeds the legislative limits (pH of 4.5 at the dredge pond and pH 5.9 at the dam). The quality does not comply with the legislation limits due to the low pH but is within the drinking water quality guideline limits. This point is a recipient of the MSP effluent;
- The surface water quality is within the legislative limits at Lanti, except pH that exceeded the limits in August 2017. The determinants elevated above background levels include TSS, turbidity, sulfate, nitrate, manganese, nickel, selenium and zinc. Aluminium concentrations are elevated relative to the drinking water guideline limits and the pH is also below the drinking water guidelines limit;
- At Gangama operations, the quality of G5 dam water is comparable to the background water quality except nitrate concentrations that are slightly elevated relative to the background levels. Further down gradient from the MSP area, the water quality appears to be impact by mining activities indicated by acidity (pH of 5.8) and elevated dissolved aluminium content;
- Nitti Port surface water has elevated aluminium, chloride and magnesium concentrations relative to the background levels and consequently increased salinity (EC and TDS). Aluminium concentrations exceed the drinking guidelines limits. Nitii Port is affected by the tidal fluctuations; and

- Water levels in the G5 pond have been monitored from late December 2016. Approximately 90 mm of rainfall fell by 20 April 2017, which resulted in a significant decline in water levels noted, which stabilised at this level until late May 2017 (see Figure 10-2). Approximately 300 mm of rainfall fell during the latter part of May 2017, before an increase in water levels occurred. Thereafter, 700 mm fell which resulted in the quick increase from mid-July 2017 onwards. This is a similar trend to the other dams.

A summary of the major impacts are as follows:

- Construction of dams and ponds attenuate flood peaks resulting in changes in seasonal flooding patterns which affect sediment loading, sediment deposition on floodplains, aquatic ecosystem and local communities / residents;
- Increase in flooding in the Gbeni mine pit void due to lack of stormwater diversion causing an impact on operations;
- Decrease in water quality downstream of mining operations due to excess water in the mining circuit as well as inadequate stormwater management results in sediment laden discharge from the mining operations;
- Dam walls being overtopped or failing as a result of freeboard requirements not being sufficient and a large flood event occurs;
- Discharge of acidic water from the MSP and Lanti operation leading to reduction in pH and increased acidity resulting in acidic, soft and corrosive water affecting the natural water system; and
- Potential use of acidic, soft and corrosive water at Lanti Dry Mine process plant resulting in corrosion and damage of metallic structures, equipment and pipes.

A summary of the major mitigation measures proposed are as follows:

- Construct an adequate stormwater management system to separate natural and mine impacted runoff;
- Continue surface water quality monitoring on a monthly basis;
- Investigate the removal of the dams to allow the natural functioning of the ecosystems in consultation with the Mine Closure Plan;
- SRL should review the reservoir hydrology and spillway design depending on the mine closure plan recommendations regarding the dams;
- Investigate if an early warning system could be implemented to ensure that the people downstream of a dam wall that is showing evidence of failing integrity or about to be overtopped, are informed so that they can vacate the area of concern;
- Regular dam safety inspections should be conducted;
- Piezometers have been installed in some of the dam walls and a tailings storage facility management plan is in place. The operation confirms to ANCOLD standards and the dams have an operating procedure in place;
- A dam break study should be investigated to identify the zone of influence as a dam wall failing could be catastrophic;
- The water balance should be looked at in greater depth with actual measured values being introduced to greater effect so that confidence can be built into the water balance and the projections made from it. This investigation is currently underway; and
- The formal dams should have a 1.8 m to 2 m freeboard, while tailings dams should have 0.8 m of freeboard.

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Sierra Rutile Limited (SRL)). The opinions in this Report are provided in response to a specific request from SRL to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

List of Abbreviations

ANCOLD	Australian National Committee on Large Dams
CET	Coarse Electrostatic Tailings
COD	Chemical Oxygen Demand
DTM	Digital Terrain Model
EC	Electrical Conductivity
EEC	European Economic Commission
EMPs	Environmental Management Plans
ESHIA	Environmental, Social and Health Impact Assessment
ESIA	Environmental and Social Impact Assessment
FET	Fine Electrostatic Tailings
GIIP	Good International Industry Practice
HEC-RAS	Hydraulic Model developed by US Army
ICP	Inductively Coupled Plasma
IFD	Intensity Frequency Duration
IT	Ilmenite Tailings
LIDAR	Light Detection and Ranging
LOD	Limits of Detection
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mRl	Mean Reduced Level
MSP	Mineral Separation Plant
NNP	Net Neutralisation Potential
PAG	Potentially Acid Generating
PCSWMM	Name of hydrological and hydraulic model
QA/QC	Quality Assurance and Quality Control
RM	Rational Method
RPD	Relative Percent Difference
RRS	River Referencing System
RT	Route
RU	Runoff Unit
SADC	Southern Africa Development Community
SANS	South African National Standards
SCS	Soil Conservation Service
SFT	Sulfur Floatation Tailings
SRK	SRK Consulting (South Africa) (Pty) Limited
SRL	Sierra Rutile Limited
SWMP	Storm Water Management Plan
SWSS	Surface Water Specialist Study
Tc	Time of Concentration

TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TT	Total Tailings
WCP	Wet Concentration Plant
WHO	World Health Organization
WRSM	Water Resources Simulation Model
XRD	X-ray diffraction
XRF	X-ray fluorescence

1 Introduction

Sierra Rutile Limited (SRL) is an active mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon concentrates. The SRL operation has an existing Environmental Licence (EPA-SL030) and has previously undertaken two Environmental and Social Impact Assessment (ESIA) studies, one in 2001 and an amendment in 2012. At the time of the two Assessments, the primary mining process employed was dredge mining. However, in 2013, SRL commenced with supplementary opencast mining operations to optimally extract the ore. With the commissioning of a second dry mining operation in 2016, SRL anticipate that, over time, dredge mining will cease as the primary mining method employed at Area 1.

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1.1 Project description

The SRL operations are located in the Moyamba and Bonthe Districts in the Southern Province of Sierra Leone. The operation is located 30 km inland from the Atlantic Ocean and 135 km southeast of Freetown, see Figure 1-1 below.

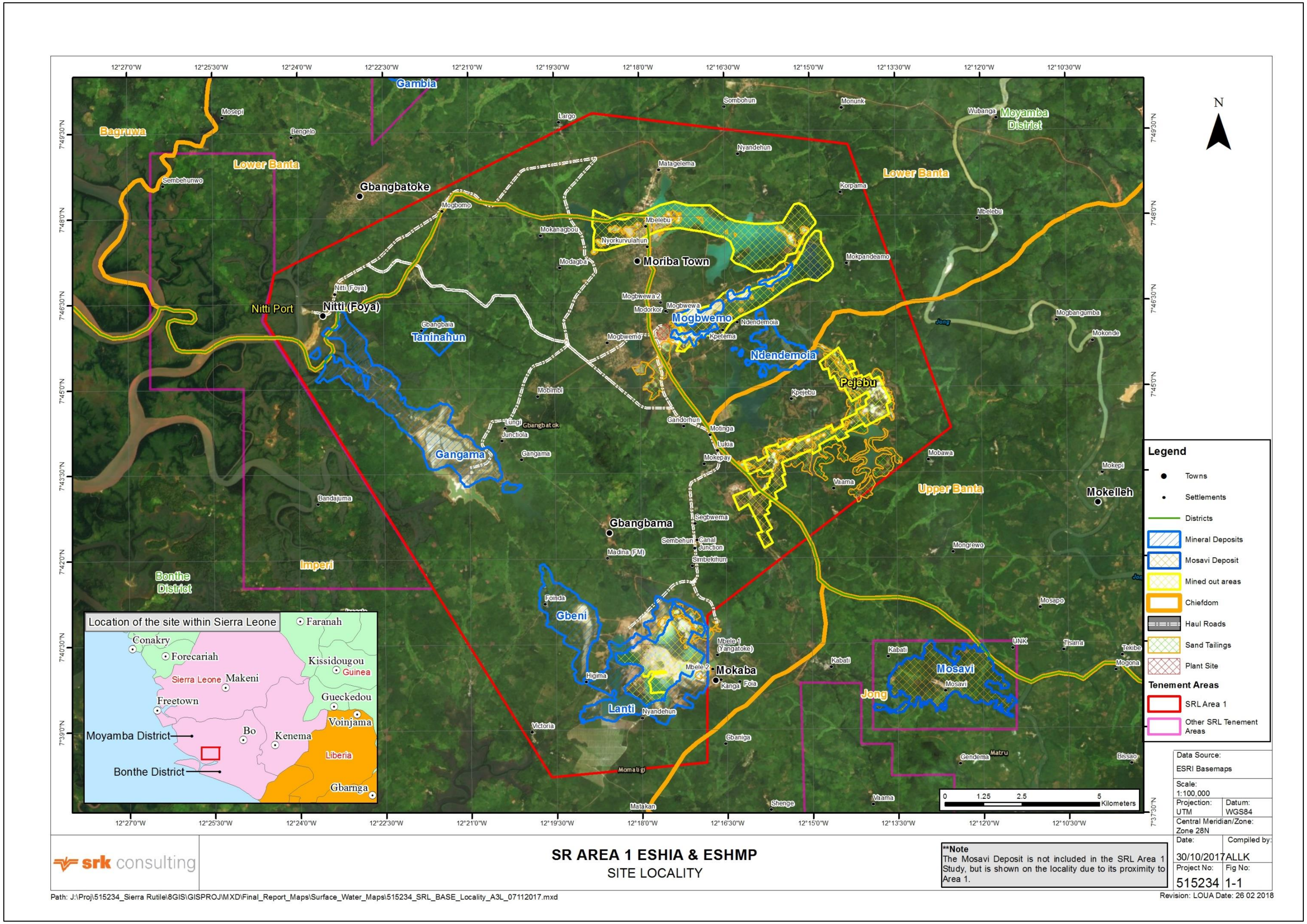

Figure 1-1: General locality map of Sierra Rutile Limited operations in Area 1

1.1.1 Mining operations

Figure 1-2 illustrates a simple depiction of the existing mining operations. Rutile occurs in the surface material and down to the bedrock. Two types of mining methods are presently employed, namely: dredge mining at Lanti operation and opencast (dry) mining at Lanti (Gbeni) and Gangama operations.

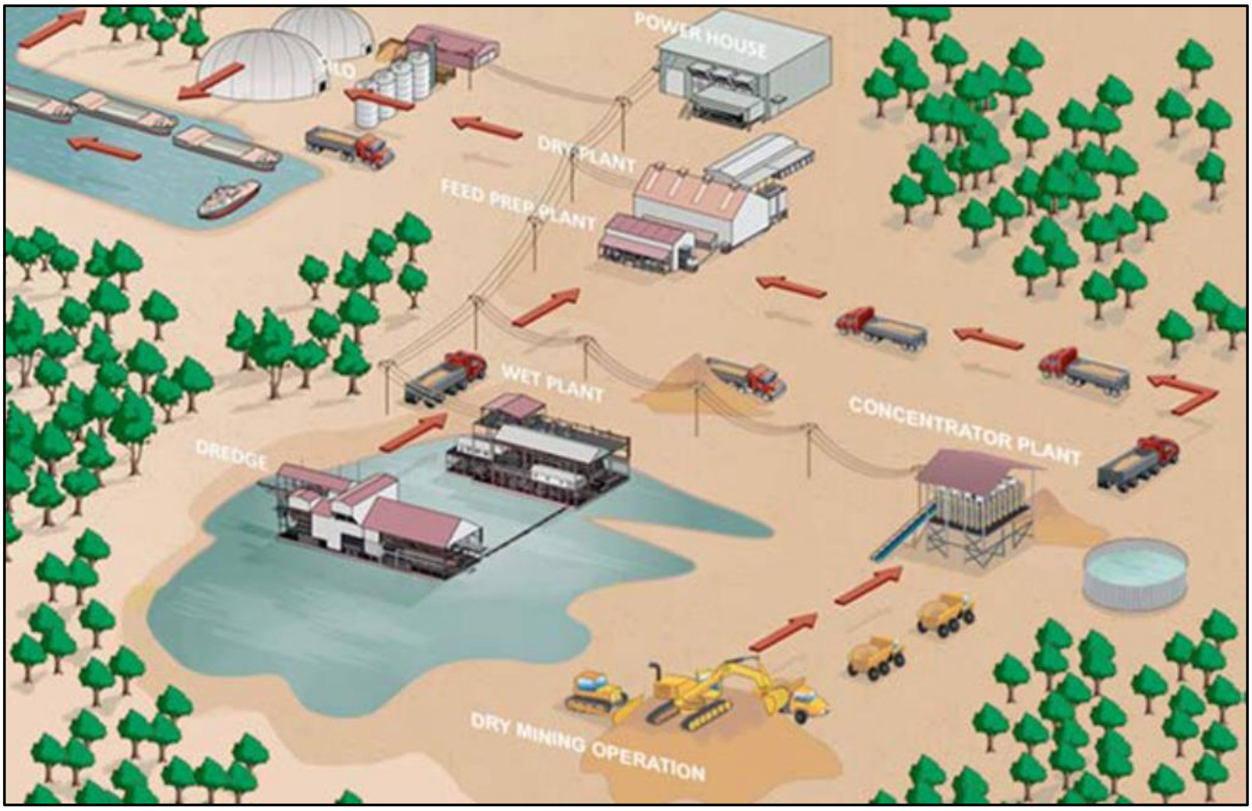

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Figure 1-2: Simplified depiction of existing mining operations

Dredge mining – Lanti

Dredge mining involves the removal of vegetation and excavation. The open pit is flooded with pumped water / harvested rainwater and dredged. The material is transferred to a floating wet concentrator for further processing.

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Figure 1-3: Lanti dredge mining and concentrator

The material is washed and scrubbed, and the coarse materials are separated from the light materials. Screening removes oversize, following which the sand is de-slimed to remove the undersize – leaving behind sand.

The dredge scrubs and screens the ore, after which it is pumped to the wet concentrator plant (WCP). De-sliming removes clay from the ore. The de-sliming process occurs in two stages. Gravity then separates the heavier minerals from the lighter minerals. The resultant heavy mineral concentrate (HMC) contains up to 60% recoverable rutile. The concentrate then goes to two separate cyclone towers: one for low sulfur ore and a second one for high sulfur ore.

The slimes (clay materials) is pumped to a containment pond and the sand is pumped to a sand stacking area.

Segregation of sulphide ore

Sulphur mineralization predominantly occurs in the deeper parts of the deposits. The mining process requires close monitoring of sulphur levels, excavation of the sulphide-rich ore, separate stockpiling of the ore and prompt delivery of the high-sulfur ore to the mineral separation plant (MSP) for processing.

For areas of varied sulphide content, SRL blends high and low-sulphide content materials.

Dry mining – Lanti, Gbeni and Gangama

The conventional load and haul method of surface mining is used at Gbeni and Lanti operations. Depending on its source, the ore is delivered to beneficiation plants by large trucks - Lanti Plant (Figure 1-4) and Gangama Plant (Figure 1-5). In 2018, in-pit mining will be commissioned at Lanti and ore will be delivered to the WCP via pumping.

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Figure 1-4: Lanti dry mining feed-preparation plant and spiral concentrator

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Figure 1-5: Gangama dry mining feed-preparation plant and concentrator

1.1.2 Processing

Final processing takes place at the Mineral Separation Plant (MSP). The MSP includes the feed-preparation plant and the dry plant, see Figure 1-6. The power plant is located adjacent to the MSP complex.

Feed-preparation plant

Trucks transport the HMC from the Lanti dredge, Lanti dry and Gangama plants to the MSP. Here the feed is loaded by front-end loaders onto a conveyor belt from where it is screened, scrubbed, de-slimed and separated using gravity methods.

Hydro-sizers are used to separate coarse and fine materials. The fine fraction is sent to a flotation plant where sulfur is removed by washing and scrubbing with chemicals that include soda ash (sodium bicarbonate - $NaHCO_3$), flotation oil (Almag oil/mineral oil – naphthenic oil and antioxidant), dowfroth 250 (propylene oxide methanol adduct - $C_7H_{16}O_3$) and potassium amyl xanthate ($C_6H_{11}KOS_2$). The resultant rutile rich feed then goes to the dry plant. The sulfur tailings is pumped to the Sulfur Flotation Tailings (SFT) pond.

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MINERAL SEPARATION PLANT, FEED PREPARATION PLANT & POWER PLANT | Project No. 515234

Figure 1-6: Mineral separation plant, feed-preparation plant and power plant

Dry plant

The material is dried, sized and separated electrostatically. Static electricity is charged through the high-tension rolls to deflect non-conductors (zircon and silica) and separate them from conductors (rutile, hematite and ilmenite). The fine and coarse tailings from the electrostatic separation are discharged to the Fine Electrostatic Tailings (FET) ponds and Coarse Electrostatic Tailings (CET) ponds.

The conductors (rutile, hematite and ilmenite) are separated magnetically to remove magnetic hematite and ilmenite and non-magnetic rutile. Ilmenite tailings are discharged to the Ilmenite Tailings (IT) pond. The surplus tailings containing a mix of materials (slimes, ilmenite etc.) are discharged to the Total Tailings (TT) pond.

1.2 Scope of the surface water study

Water is used in nearly all the processes in the mine including mining, processing, slimes disposal and potable use. The rainfall for this area is high (circa 2 800 mm/year) but is highly variable where 80% of the rainfall falls within 5 months from July to October. This highly variable rainfall leads to many potential water risks including excess water generated in the wet season that will spill to the environment, as well as a reduction in water levels in the water supply dams during the dry season. Any changes to the topography due to mining will have other water related risks that need to be identified and mitigated where possible. To understand the current water baseline and quantify how changes to the topography will impact the water resources, a surface water study was undertaken.

The following scope of work was undertaken:

- Available historical information was collected from the mine as well as other reports done in the area. This data was reviewed and used as input into the model;
- The geochemistry and groundwater specialists were liaised with and consulted as part of the preparation of this report;
- Available climate data provided was reviewed and collated as well as storm data that was analysed for the site by Golder Associates (2017);
- A 12-month water sampling programme was set up and the information for the first few months (July, August and September 2017) is included in this report;
- Baseline water chemistry was updated by incorporating the monthly monitoring data with the historical data;
- Hydrological baseline was estimated for the current situation as well as a potential situation with the dams below the MSP removed. Similarly, for the mining area, a pre- and post-mining water resource study was undertaken;
- Measurement of the flows in the rivers was initially to be done by installing a Solonist level logger but the first Solonist logger installed was stolen before any data was downloaded;
- A high-level water balance was developed using the existing data. Very little data was available and the water balance will need to be continually improved as more metered data becomes available;
- Floodlines were determined and stormwater requirements for natural and mine impacted areas were identified and sized;
- An impact assessment was conducted; and
- A report was compiled with findings of the assessment together with mitigation and management measures.

2 Legislative Aspects

Primary legislation that is applicable to Sierra Leone, relevant to the SRL project includes, but is not limited to the following. Each of the limits for the various Acts are included in the water quality section (Section 9):

a) The Environment Protection Agency Act, 2008 -
   - Overarching legislation, comprehensive application to environment protection;
   - General duty to protect the environment; 'polluter pays' and 'precautionary' principle;
   - Objectives include inter alia the coordination, monitoring and implementation of domestic policies; and
   - 'Listed activities', including extractive industries and associated infrastructure, require a comprehensive EIA.

b) The Mines and Minerals Act, 2009 -
   - Prior to the commencement of any activity, mining companies must receive a valid environmental licence;
   - Environmental management plans must be regularly amended and approved, specifically, the diversion of any watercourse;
   - The water supply should not be altered in such a way that would prejudicially affect the water supply enjoyed by another person; and
   - The administration of dredge permits will consider efficiency and possible adverse effects to the environment.

c) Environment Protection Act, 2000 and Regulations – Refer to section 34 of the act
   - Effluent quality standards may not be lower than the water source;
   - The EIA shall propose control checkpoints for every effluent generated from the operations; and
   - Effluent water must be separated, controlled and discharged.

d) The Sierra Rutile Amendment (Ratification) Act, 2002 -
   - The Company's mining operations will include mining in the river beds, streams and watercourses; and
   - The Company is permitted to use the water from any natural watercourse and return the same together with the spoils so long as there is no poisonous or noxious discharge.

e) The Environment and Social Regulations for the Minerals Sector, 2012. These regulations were promulgated under the environment Protection Agency (Amendment Act), 2010 Protection (Mines and Minerals) Regulations, 2013 -
   - Refer to section 56 (1) to (3), section 61(1), section 62, section 65 (1) (a) to (d) and (2), section 66.

Over and above the legislation listed above, the water quality was guided by the following guidelines:

- The World Bank Group Environmental, Health and Safety (EHS) Guidelines for Mining (2007);
  - Refer to section 2.1 "Emissions and Effluent Guidelines" and "Table 1, Effluent Guidelines".
- The surface water at SRL is consumed and used by the local communities. However, without identifiable and prescriptive domestic drinking water standards, the water quality is compared with the following sources -
  - World Health Organisation (WHO) Guidelines for Drinking Water 2017;
  - South African Standard for Drinking Water (SANS 241-1:2015) – to assist with a holistic assessment; and
  - EHS Guidelines for Mining (IFC EHS), 2007.

In the absence of prescribed guidelines for stormwater management, SRK relied on Good International Industry Practice (GIIP) to complete the study. The 1:50 year standard was used to identify the adequacy and / deficiency of the stormwater infrastructure at SRL.

3 Climate

3.1 Rainfall

SRL provided SRK with monthly rainfall records for the MSP site (2001 to 2017) and Lanti operation (2001-2007, and 2013-2017). SRL also provided daily rainfall data for the period of 2013 to 2017 for the Lanti, Gangama, Sembehun and Nitti sites.

The average rainfall for the MSP is estimated to be around 2 800 mm/year. The wet season typically begins in May and ends in November with the highest average monthly rainfall reading of 651 mm (in August). The dry season, begins in December and ends in April. The average rainfall during the dry season varies from a minimum of 6 mm in January to a maximum of 97 mm in April.

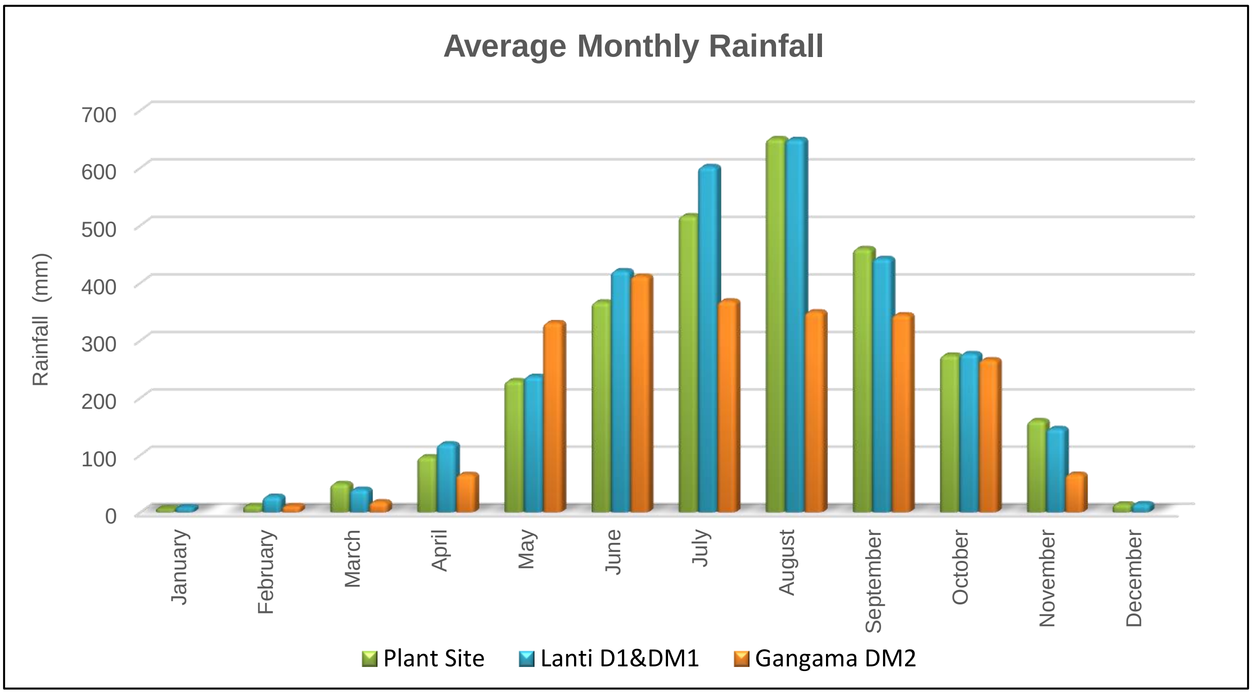
It should be noted that there was 10 months of data was missing from the rainfall record between the dates of August 2014 to August 2017 (wet season). However, the average rainfall for this period was calculated to be 2 933 mm. The Lanti operation measured an average monthly rainfall of 2 231 mm/year from 2013 to 2017.

A summary of the average monthly rainfalls for the MSP site, Lanti operation and the Gangama operation is presented in Table 3-1 below.

Table 3-1: Average monthly rainfall comparison (mm)

Sites	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
MSP	6	11	50	97	230	367	516	651	460	274	160	14	2 836
Lanti	9	28	40	119	237	421	602	649	442	277	146	15	2 985
Gangama	-	11	18	66	331	411	368	350	344	266	66	-	2 231

The monthly distribution of rainfall, maximum and minimum readings, average and percentile readings at the MSP are presented in Table 3-2. The results indicate the non-exceedance percentile. The MSP site data is reliable because the rainfall is recorded over a period of more than 10 years. The table should be read as follows: The total monthly rainfall will be equal to, or less than, 52 mm, 98% of the time. Conversely, the result indicates that 2% of the time the monthly rainfall will exceed 52 mm.



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AREA 1 SURFACE WATER
AVERAGE MONTHLY RAINFALL COMPARISON

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515234

Figure 3-1: Average monthly rainfall comparison

Table 3-2: Percentile and distribution of rainfall events (mm/month)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	0	0	0	23	0	256	255	450	271	151	55	0
Max	55	50	124	204	393	480	887	829	575	415	242	47
Average	6	11	50	97	230	367	516	651	460	274	160	14
10%	0	0	4	46	83	264	312	497	319	192	67	0
30%	0	0	19	71	221	313	446	617	416	245	159	3
50%	0	4	58	95	231	379	476	657	480	285	176	11
70%	0	14	75	116	304	429	580	700	530	312	192	19
90%	21	32	92	148	345	460	728	791	564	327	215	33
95%	47	41	108	176	364	473	856	817	569	352	229	37
98%	52	46	117	193	382	478	875	824	573	390	237	43

Note: There is approximately 95% chance that 47 mm or less will fall in the month of January.

3.2 Evaporation

The mean annual evaporation (class A-pan) data was calculated using the 1966 Torma Bum evaporation station measurements. Albeit incomplete, the pan evaporation data was used to interpolate the Torma Bum data and reconcile the missing figures. Original and reconciled monthly A- pan evaporation figures from Torma Bum evaporation station were used in the water resource rainfall-runoff model and are presented in Table 3-3 and Table 3-4 below. The A-pan evaporation data was converted to S-pan evaporation data. A-Pan evaporation is measured using a circular tank which is filled with water and then the drop in depth is converted to a loss in evaporation. The difference between the A-pan and S-Pan data is that the A-Pan is situated above ground while the S-Pan is situated below the ground.

Table 3-3: Monthly evaporation (mm) - Torma Bum

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
A-pan (mm)	-	114	135	122	109	91	-	-	-	84	84	101	
Piche (mm)	78	106	124	90	71	45	40	32	39	43	51	53	772

The reconciled monthly class A-pan and class S-pan are presented in Table 3-4.

Table 3-4: Monthly class A-pan and class S-pan (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
A-pan (mm)	84	114	135	122	109	91	72	54	56	84	86	101	1 108
S-pan (mm)	58	84	102	91	80	64	47	31	33	58	59	73	779
Distribution (%)	7.3	11.2	13.6	12.1	10.4	8.2	5.9	3.8	4.0	7.0	7.3	9.1	100

3.3 Storm rainfall

The storm rainfall depths for SRL were obtained from the Intensity Frequency Duration (IFD) study (Golder Technical Memorandum, 2017). The MSP site data was specifically used because the IFD curves can only be calculated using data observed for more than 10 years.

The IFD curves for different recurrence intervals and estimate design rainfall is presented in Table 3-5. These curves were calculated for the following periods of rainfall: 5 minutes, 10 minutes, 30 minutes, 45 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 8 hours, 10 hours, 16 hours, 20 hours, 4 days, 5 days, 6 days and 7 days.

The rainfall design is presented in Table 3-6.

Table 3-5: Intensity Duration Frequency (IFD) estimates for SRL (mm)

Duration (minutes)	Average Recurrence Intervals (ARI) (mm)							Duration (hours)
	1:1	1:2	1:5	1:10	1:20	1:50	1:100	
180	69.6	106.8	138.6	159.9	180.6	207.6	228.0	3
360	90.6	128.4	168.0	189.6	222.0	262.8	294.0	6
720	106.8	152.4	189.6	214.8	247.2	294.0	336.0	12
1 440	120.0	168.0	211.2	235.2	268.8	314.4	362.4	24
2 160	129.6	183.6	230.4	255.6	284.4	324.0	370.8	36
2 880	139.2	196.8	244.8	273.6	297.6	336.0	374.4	48
4 320	151.2	208.8	259.2	288.0	309.6	338.4	381.6	72

Table 3-6: Storm design and rainfall depths (mm)

Return Period (Years) / Rainfall Period		1:2	1:5	1:10	1:20	1:50	1:100
5	Minutes	2	4	14	44	80	81
10	Minutes	13	46	46	74	110	116
15	Minutes	27	46	64	94	128	138
30	Minutes	50	72	90	118	152	170
45	Minutes	62	87	105	135	170	190
1	Hour	72	98	116	146	182	200
1.5	Hours	83	111	129	159	196	216
2	Hours	94	124	142	172	210	232
4	Hours	116	150	170	200	238	266
6	Hours	128	168	189	222	263	294
8	Hours	138	176	198	227	264	298
10	Hour	144	184	208	236	274	308
12	Hours	154	189	214	247	294	336
16	Hours	160	178	203	239	297	337
20	Hours	167	210	236	262	300	338
24	Hours	168	211	235	269	314	362
1	Day	184	230	256	284	324	371
2	Days	197	245	274	298	336	374
3	Days	209	259	288	310	338	382
4	Days	216	268	302	320	363	408
5	Days	226	270	307	330	372	424
6	Days	230	284	312	340	376	432
7	Days	234	289	318	344	385	438

3.4 Temperature

The monthly temperature data used for the study was sourced from the Weather Base website (available at http://www.weatherbase.com/) for the Mogbwemo area which is 2 km west from the MSP. The average monthly temperatures ranged between 25.3 °C - 28.1 °C, with the maximum reaching 33.4 °C and minimum reaching 19.8 °C. Daily temperatures during the rainy season are up to 5 °C lower than in the dry season. Table 3-7 presents the Mogbwemo average, minimum and maximum temperatures. The data is also graphically represented in Figure 3-2.

Table 3-7: Mogbwemo monthly temperatures (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	25.7	27.3	27.9	28.1	27.3	26.4	25.4	25.3	25.9	26.5	26.7	26.1
Maximum	31.2	32.9	33.4	32.8	31.6	30.1	28.3	28.2	29.4	30.3	30.9	31
Minimum	19.8	21.1	21.8	22.6	22.7	22.3	22	21.9	22.1	22.1	22	20.6

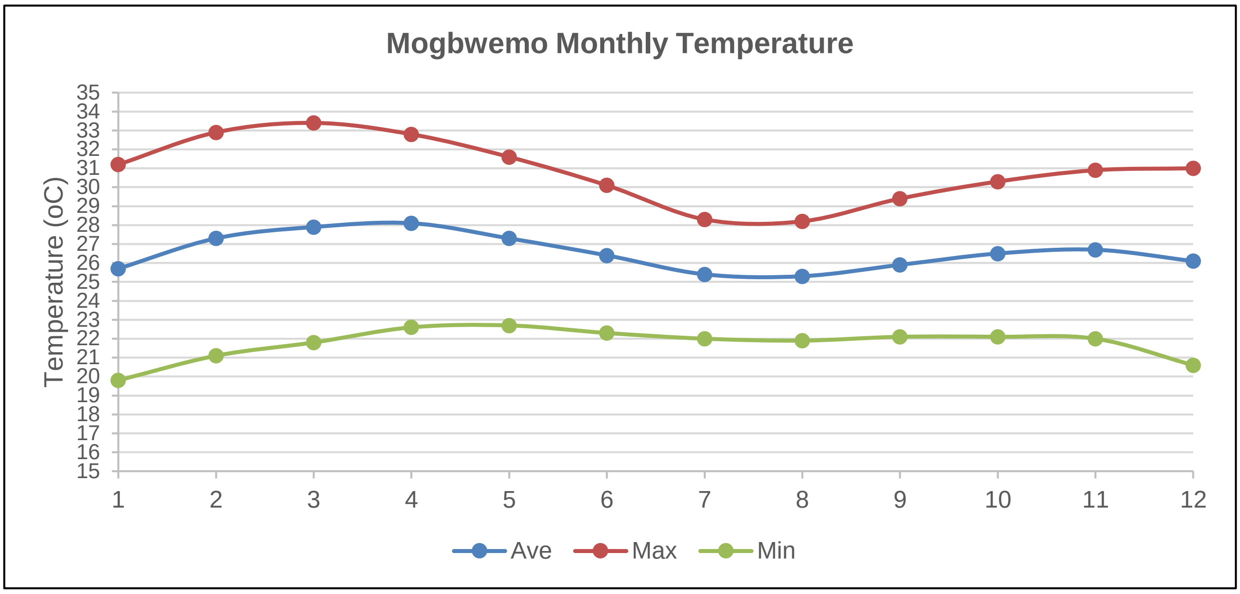

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Figure 3-2: Mogbwemo monthly temperature (°C)

3.5 Humidity

Humidity data for the study was sourced from the Weather Base website (available at http://www.weatherbase.com/) for the Mogbwemo area. The relative monthly humidity figures are presented in Table 3-8. Relative humidity ranged from 68.6 – 87.4%, with higher figures measured during the wet season and lower figures measured in the dry season. The data is also graphically represented in Figure 3-3.

Table 3-8: Monthly relative humidity (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mogbwemo	70.3	71	68.6	70.4	79.9	82.6	86.8	87.4	84.8	81.6	79.6	75.7

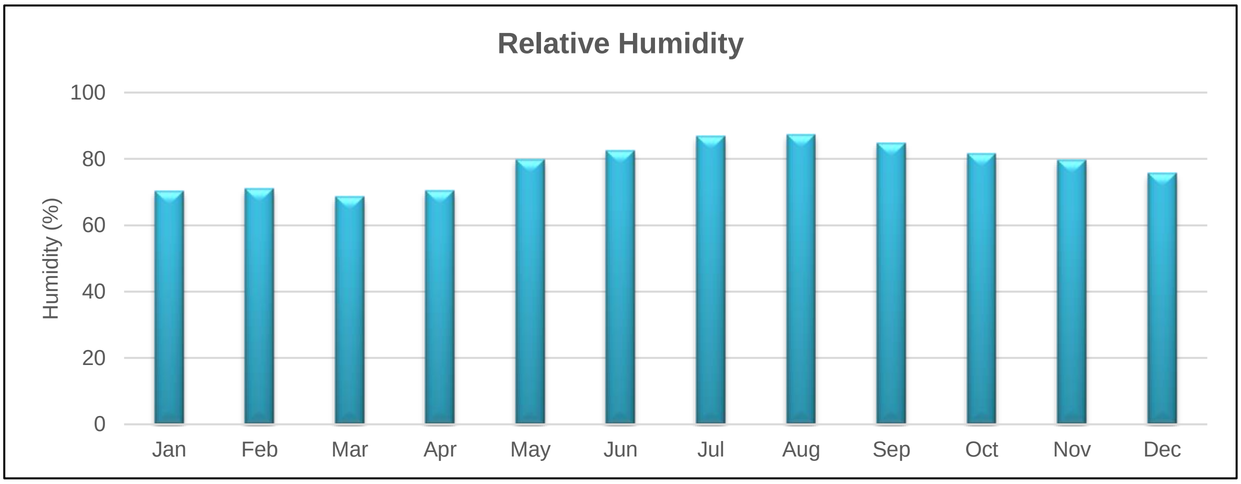

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Figure 3-3: Mogbwemo monthly relative humidity

4 Water Resources

The surface water resources at the mine have been significantly changed from natural flow conditions. The historical mining areas are now largely ponded areas and the outflows into the natural river systems are via spillways from these impoundments. These dams are not ideal (as is explained later in Section 11.3). In order to identify what the current flow regime and the potential impact of removing the dams will have on the water resources a runoff model was prepared. Runoff for the current situation was modelled and then a simulation of what the flows in the river could be if the dams were removed (or reduced in size) was undertaken. This section shows the current and future runoff in the rivers.

4.1 Methodology

4.1.1 WRSM model background

The hydrological analysis involves processes to determine the rainfall-runoff relationship of the catchment using rainfall-runoff models, in this case the Water Resources Simulation Model 2000 (WRSM2000), which forms the basis of this analysis.

WRSM2000 is a mathematical model to simulate the movement of water through an interlinked system of catchments, river reaches, reservoirs, irrigation areas and mines. WRSM2000 is of a modular construction (running under Windows), with five different types of modules (runoff, reservoir, irrigation, channel and mine) linked by means of routes. The routes represent lines along which water flows, such as river reaches. The model was first developed in 1969 and has been subject to numerous enhancements over the years.

WRSM2000 has been used to analyse the hydrology on a monthly time scale for a number of diverse applications - ranging from very small to very large catchments varying in complexity from being totally undeveloped to highly developed catchments. WRSM model has its origin in United States of America and has been used throughout South Africa and Southern Africa Development Community (SADC) countries.

Some common uses of the model are:

- For broad regional assessment of water resources;
- To produce naturalised flow records i.e. remove man-made land-use effects; and
- To estimate flows in ungauged catchments.

4.1.2 WRSM2000 model configuration

Network diagrams were established for each River system. The River systems are indicated on Figure 4-1 and summarised below:

- S1, S11 and S12A – This system includes all the sub-catchments draining runoff towards the outlet of sub-catchment S1E, (SIA S1B, SIC, S1D, S1E, S11A, S11B, S11C and S12A);
- S2-S5 - This system includes sub-catchments S2, S3, S4 and S5;
- S6;
- S7;
- S8;
- S9;
- S10 and S12B – This system includes sub-catchments S10A, S10B and S12B;
- S12 - This system includes sub-catchments S12C, S12D and S12E; and
- S13.

The WRSM2000 model for the S2_S5-System (selected as an example) was configured as indicated in Figure 4-1 below. Each Runoff Unit (RU) represents the runoff from the incremental catchment area upstream of the river outlet. The Reservoir Module, RV1 collects runoff from the Runoff Module/unit and spills into the downstream route when full. The mining module accounted for in system S1, S11, S12A, system S8 and system S10 and S12B were used to simulate runoff generated by mining activities. Mining modules are associated with runoff modules due to the fact that they reduce the area of the Runoff Module in which they lie. Following the preparation of all required data to model each River System, WRSM was used to simulate flows for the period 2001 to 2016. Calibration parameters controlling subsurface flow, soil moisture, infiltration, soil evaporation, etc., were selected based on data and photographic images obtained during site visit. A description of the functioning of each parameter is given in Table 4-1.

4.2 Surface water hydrology

Area 1 lies in Southern Province of Sierra Leone, in between East Teso River and west of Jong (Taia River), which are among some of the major rivers in Sierra Leone. The mining area catchment/surface river system drains in three different directions as described below for the MSP, Lanti and Gangama mining areas (see Figure 4-1).

The MSP catchment system (S12D, S12C, S12E S13, S10A, S10B) which is east of the Area 1 lease boundary, consists of three of the catchment river systems (Kopa, Tikote, and Kokpoi Streams), which flow east into the Jong River.

The Lanti catchment system consists of catchments (S6, S7, S8A to S8E) and includes the Gbeni and Lanti streams (see Figure 4-1). Gbeni stream is located on the southern portion of the mining Area 1 and it flows to the southwest before joining the Lanti stream to form Teso Creek. The Teso Creek flows into the Sherbro River which eventually flows into the sea. The Teso Creek is influenced by tidal action.

The Gangama catchment river system (Gbangbaia Creek, Jangalo Creek and Gbangbatoke - S1, S11 and S12A), is located east of Area 1. The catchment drains in Gbangbaia Creek which flows into Bagru Creek. The Bagru Creek flows to Sherbro River which then flows into the sea.

The model parameters that were used in the study are presented in Table 4-1.

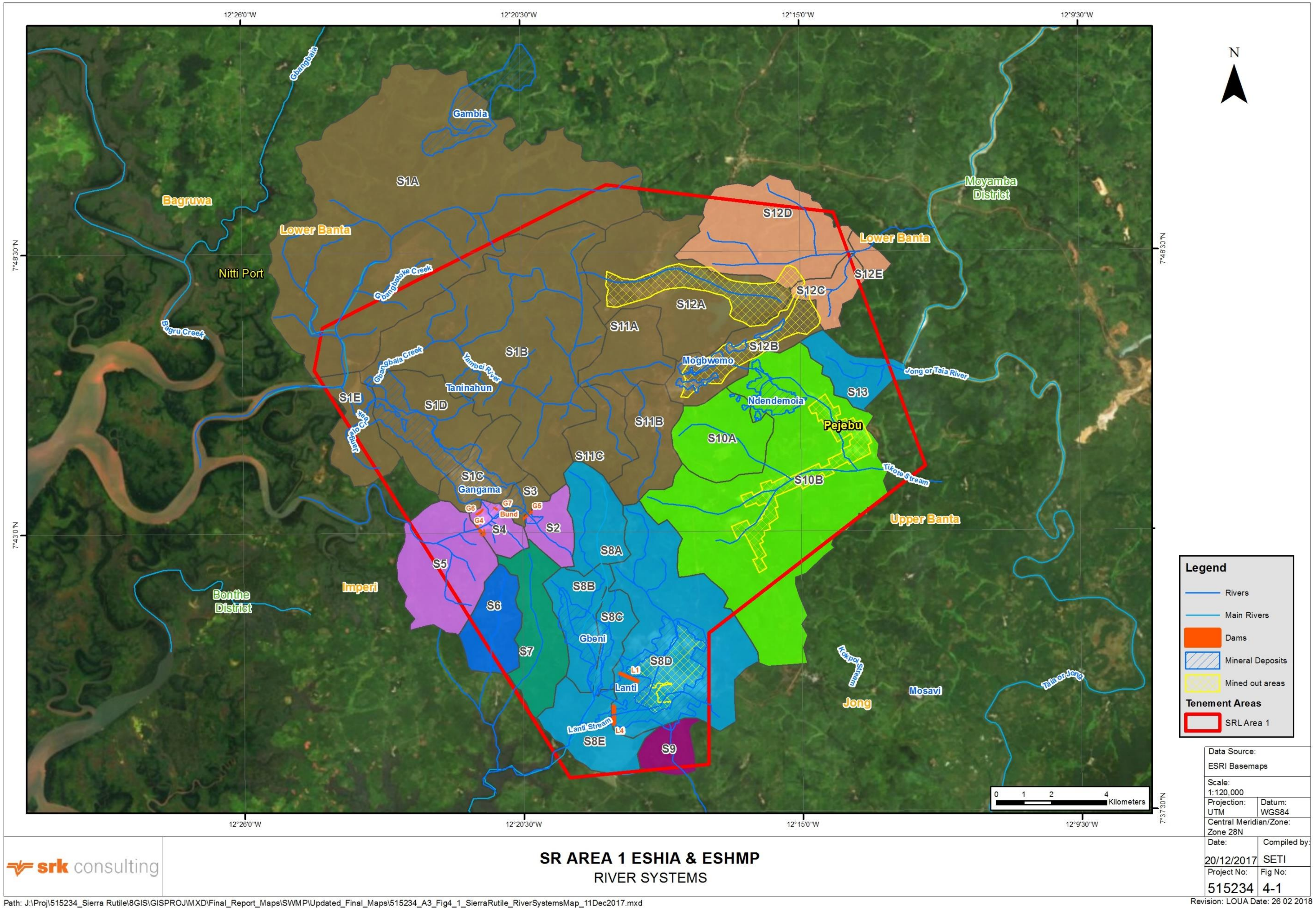


Figure 4-1: Area 1 river systems and major catchment areas

Table 4-1: Catchment areas contributing to runoff at the nine catchment exit points

Model Parameter	Description	Parameter Used	Action
POW	Determines rate at which subsurface flow reduces as soil moisture is depleted	3	A POW of 3 indicates that the subsurface flow will drops rapidly during periods between rainfall events
SL	Soil moisture level below which all subsurface flow ceases	0 mm	Baseflow will cease once the soil reaches field capacity
ST	Moisture holding capacity of the soil	750 mm	The entire study area is generally wet and this value represents a high moisture holding capacity.
FT	Maximum rate of subsurface flow at soil moisture capacity	20 mm/month	A value of 20 mm for FT indicates a high subsurface flow potential
GW	Splits soil moisture into upper (faster response - see TL) and lower (slower response - see GL) zones	20 mm/month	A high GW value of 20 mm reduces the standard deviation signifying increasing base flow
PI	Interception storage	1.5 mm	This parameter represents the depth of rainfall captured on the vegetation before rainfall lands on the forest floor.
TL	Lag of surface runoff and subsurface flow from the upper zone (see GW)	0.25	Indicates a significant delay of runoff in response to rainfall
GL	Lag of subsurface flow in the lower zone (see GW)	2.5	Indicates a significant delay of seepage to the deeper soil layers in response to rainfall
R	Controls the rate at which evaporation reduces as soil moisture is depleted	0.5	The value indicates a high rate at which evaporation reduces as soil moisture is depleted hence an overall reduction in flow is obtained

The river is represented by the numbered arrows or Routes (RT). The routes represent lines along which water flows. Most hydrological systems can be represented by means of the different types of modules, linked using routes. The Channel Reaches (CR) only act as junction nodes indicating a confluence of two or more river stretches.

The output from the WRSM2000 rainfall-runoff modelling is the simulated runoff sequence of total monthly volume in million cubic metres for each of the months, and summarised as total annual volume for each of the years. A runoff sequence was developed for each river system and the summary of the results in given in Table 4-3 to Table 4-6 below. The flow values in these tables represent the mean annual runoff (MAR) generated from rainfall after taking rainfall and evaporation, reservoirs and mines (where applicable) into account.

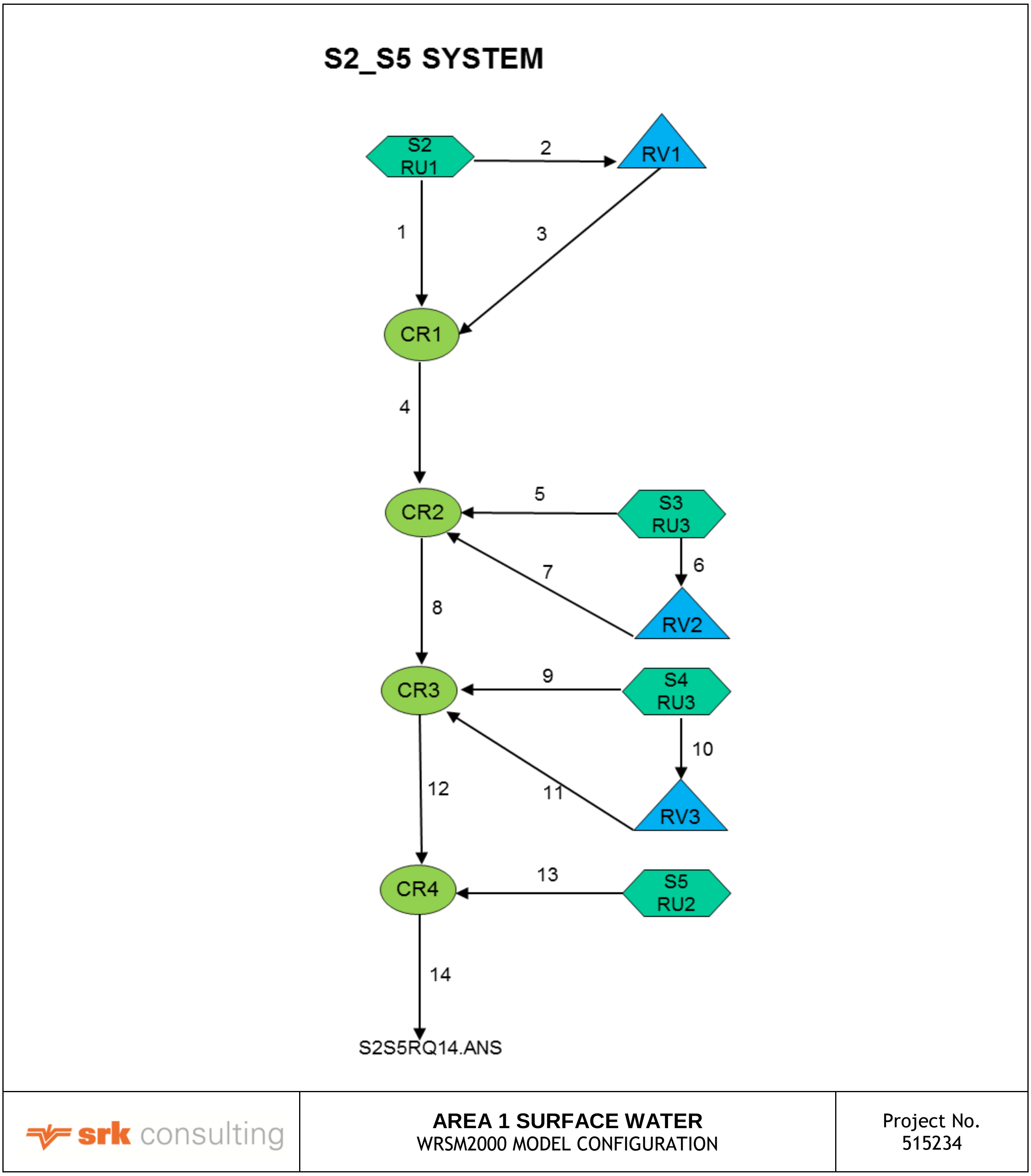


Figure 4-2: WRSM2000 model configuration (River system S2_S5)

The catchment rainfall and evaporation data discussed in Sections 3.1 and 3.2 were used as input to the WRSM2000 model. The mean annual runoff (MAR) at each storage dam was calculated based on the catchment area (see Table 4-1). S2_S5 River system selected as an example (selected as WRSM model configuration in Figure 4-2 above) has a total cumulative area of 20.2 km^2 as indicated in Table 4-2 below.

4.3 Catchment characteristics

The catchments upstream of the nine river systems listed in Section 4.1 above were delineated and the catchment areas contributing to the runoff at the exit of each sub-catchment were determined from the contour map produced from the 10 m contours. The catchment areas contributing to the runoff at the exit point of each system are given in Table 4-2 and graphically shown in Figure 4-2.

Table 4-2: Incremental catchment area contributing to runoff at the nine catchment exit points (including dam areas)

River system	Sub-catchments within River system	Area (km^2)
S1, S11 and S12A	S1A	78.8
	S1B	42.9
	S1C	6.1
	S1D	11.6
	S1E	6.8
	S11A	6.9
	S11B	7.3
	S11C	5.3
	S12A	21.3
Cumulative Total Area S1, S11 and S12A		**187**
S2, S3, S4 and S5	S2	3.5
	S3	1.7
	S4	2.6
	S5	12.4
Cumulative Total Area S2, S3, S4 and S5		**20.2**
S6	S6	6.2
Cumulative Total Area S6		**6.2**
S7	S7	8.7
Cumulative Total Area S7		**8.7**
S8	S8A	6.6
	S8B	6.5
	S8C	3.5
	S8D	27.7
	S8E	7.6
Cumulative Total Area S8		**51.9**
S9	S9	3.3
Cumulative Total Area S9		**3.3**
S10 and S12B	S10A	8.7
	S10B	48.3
	S12B	8.3
Cumulative Total Area S10 and S12B		**65.3**
S12	S12C	3.5
	S12D	16.7
	S12E	1.3
Cumulative Total Area S12		**21.5**
S13	S13	5
Cumulative Total Area S13		**5**

The hydrological analysis involves processes to determine the rainfall-runoff relationship of the catchment using rainfall-runoff models. In order to configure and to populate these rainfall-runoff models data sets in terms of rainfall, evaporation, contributing catchment size and slope etc. are required.

The level of confidence placed on the results of a hydrological study is largely dependent on the quality of the data and information used in the analyses. The information requirements for this purpose are diverse, covering hydro-meteorological data such as time-series of rainfall and streamflow as well as information on historical water use and the descriptions of the physical characteristics of the system. Rainfall data used in the hydrological analysis of the nine river systems was obtained from SRL, due to lack of recent evaporation data for the Area 1, evaporation data discussed in Section 3.2 for the evaporation station Torma Bum (measured in 1966) was used as one of the inputs into WRSM model. Catchment data and catchments slopes were calculated from the 10 m contours provided.

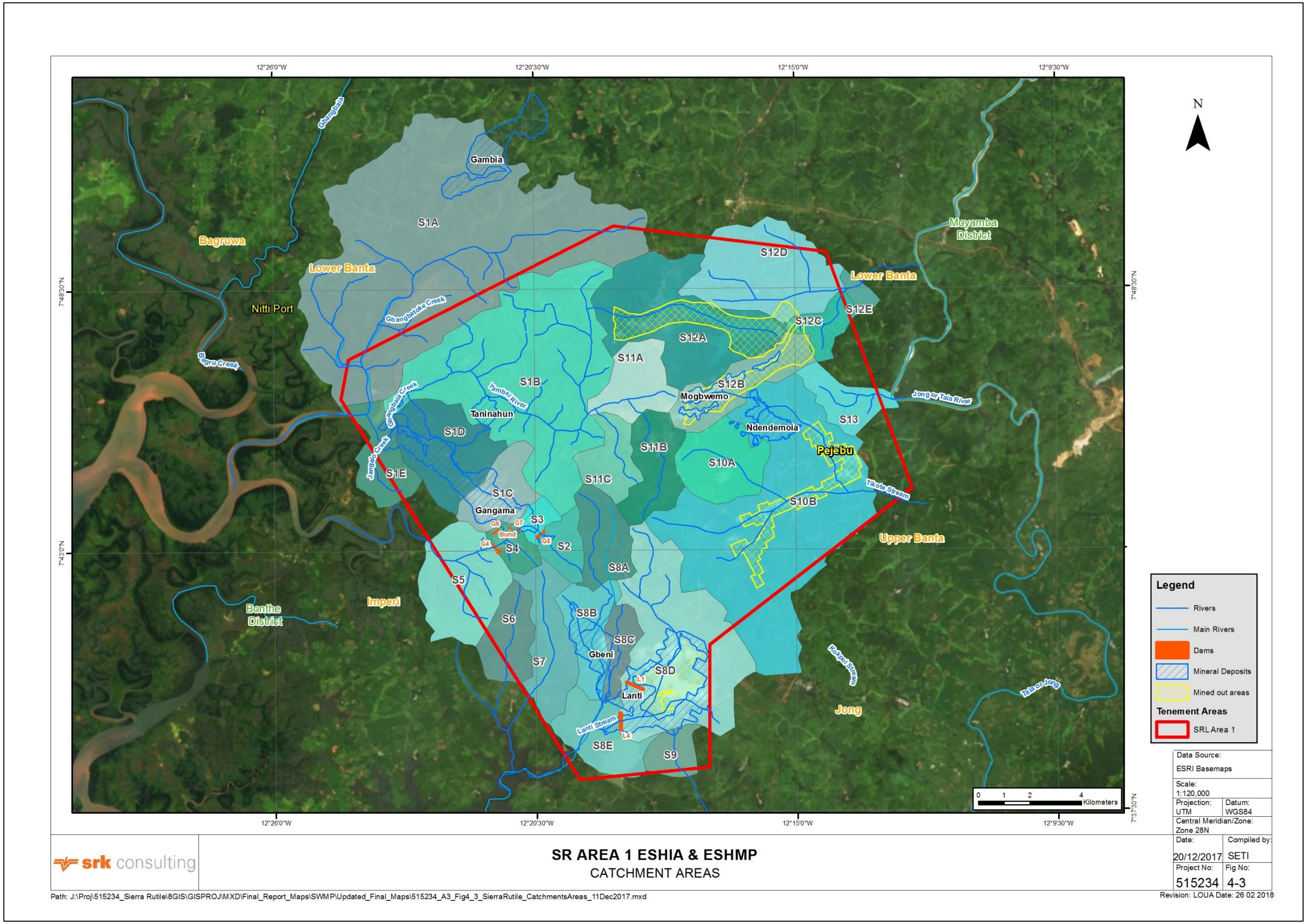


Figure 4-3: Area 1 catchment areas

4.4 Flow results

The output from the WRSM2000 rainfall-runoff modelling is given as the simulated runoff sequence of total monthly volume in million cubic meters (Mm^3) for each of the months and summarized as total annual volume for each of the years. The runoff sequence was developed for all the systems (S1, S11 and S12A to S13). The runoff sequence for the nine main systems and are shown in Table 4-2 and the Mean Annual Runoffs are indicated in Table 4-3.

A statistical analysis was conducted on the WRSM2000 streamflow data in Table A1 to Table A10 of Appendix A to determine the frequency of occurrence of specific flow events. The streamflow data was ranked for each month independently from the highest to the lowest flow value over the 16-year period, with the lowest flow for each month ranked as no. 16 and the highest flow for each month ranked as no. 1. The percentiles (the flow value below which a certain percentage of flows occur) and probability that a certain flow event will be exceeded in any given year (as a percentage of time) were calculated for each of the 16 flow values for all 12 months of the year. The percentiles are given in Appendix A.

Table 4-3: Mean Annual Runoff (MAR) at each river system

Site	Cumulative catchment (km^2)	Mean Annual Runoff (MAR) (Mm^3)
S1, S11 and S12A	187.0	51.97
S2, S3, S4 and S5	20.2	4.26
S6	6.2	1.32
S7	8.7	1.86
S8	51.9	12.41
S9	3.3	0.70
S10 and S12B	65.3	12.97
S12	21.5	4.59
S13	5.0	1.07

The flow values in Table 4-3 represent the MAR generated from rainfall after taking catchment evaporation, dam evaporation and mining activities into account. Any abstractions from the river (including the environmental water requirements), irrigation, afforestation and alien vegetation are excluded from the results given in Table 4-3.

The flows into and out of each dam/pond are outlined in Table 4-4 below.

Table 4-4: Mean Annual Runoff (MAR) into and out of the dams/ponds

River system	Dam/pond name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR into the dam (Mm^3)	MAR out of the dam (Mm^3)
S1, S11 and S12A	Titan (S11B)	0.15	0.12	0.10	0.08	0.06	0.05	0.05	0.09	0.21	0.25	0.22	0.19	1.56	1.54
	Bamba Belebu Pond (S12A)	0.44	0.35	0.28	0.22	0.17	0.15	0.14	0.27	0.6	0.72	0.65	0.54	4.53	4.26
S2, S3, S4 and S5	G5 (S2)	0.07	0.06	0.05	0.04	0.03	0.02	0.02	0.04	0.10	0.12	0.11	0.09	0.75	0.73
	G7 (S3)	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.05	0.06	0.05	0.04	0.36	0.35
	G4 (S4)	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.03	0.07	0.09	0.08	0.07	0.56	0.53
S8	Lanti	0.14	0.11	0.09	0.07	0.05	0.04	0.04	0.08	0.18	0.22	0.2	0.16	1.39	1.11
S10 and S12B	Motinga	0.17	0.14	0.11	0.09	0.07	0.06	0.06	0.10	0.23	0.28	0.25	0.21	1.76	1.66
	Mogbwemo	0.16	0.13	0.10	0.08	0.06	0.05	0.05	0.10	0.22	0.27	0.24	0.2	1.68	0.68
	Pejebu	0.95	0.77	0.61	0.47	0.37	0.32	0.31	0.58	1.29	1.56	1.40	1.16	9.8	9.72

The table above shows that flow out of Titan Pond is 1.54 Mm^3 per annum which is only 3% of the entire catchment runoff as the pond occupies a very small portion of the catchment. Removing the pond will cause an increase in the river runoff. The same flow behaviour is observed with removal of all the dams from their respective River systems within which they fall.

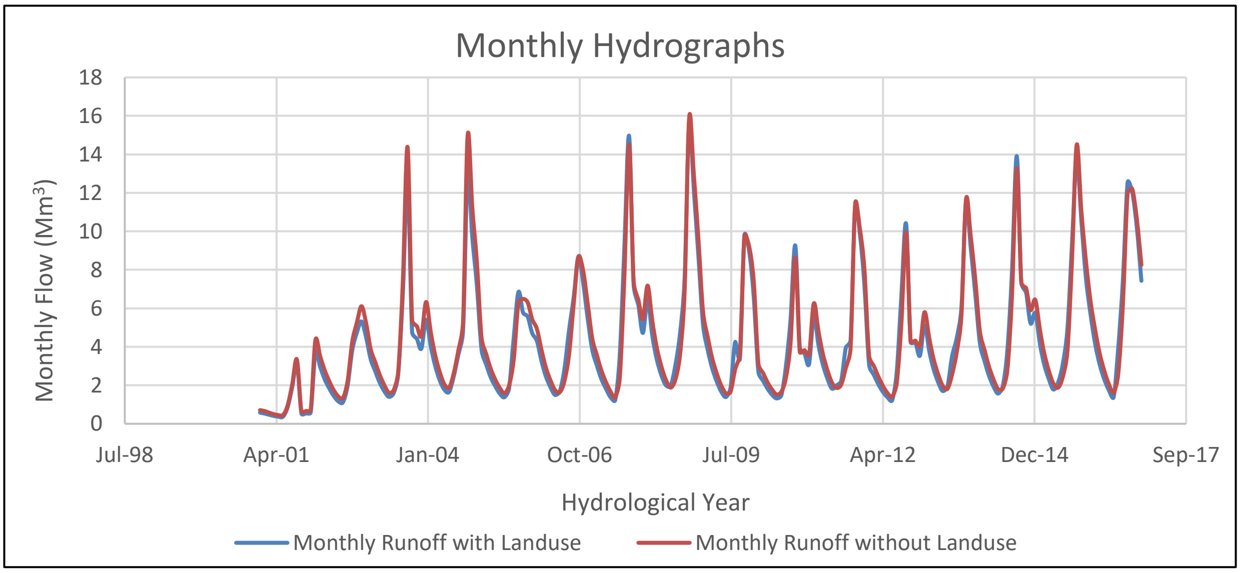
The change in flow for the nine River systems due to the presence and absence of dams is depicted in Figure 4-4 and Figure 4-7 below. Only River systems S1, S11 & S12A, River system S2_S5, River system S8 and River system S10 and S12B have dams/ponds within their catchments. The table below gives MAR with and without land-use (dams and mines) and the percentage flow reduction due to these man-made effects.

Catchment flow reduction due to these man-made effects is illustrated in Table 4-5.

Table 4-5: Mean Annual Runoff with and without dams (10^6 m^3/annum)

River system	River system MAR with dams	River system MAR without dams	% MAR reduction due to land-use change
S1, S11 and S12A	51.97	54.41	4.48
S2, S3, S4 and S5	4.26	4.65	8.39
S6	1.32	1.32	0.00
S7	1.86	1.86	0.00
S8	12.41	12.48	0.56
S9	0.70	0.70	0.00
S10 and S12B	12.97	13.94	6.96
S12	4.59	4.59	0.00
S13	1.07	1.07	0.00

Monthly flows for River systems with and without dam/ponds and mines are shown in Figure 4-4 to Figure 4-7.



srk consulting	AREA 1 SURFACE WATER MONTHLY FLOWS OUT OF RIVER SYSTEMS S1, S11 & S12A WITH AND WITHOUT LAND-USE	Project No. 515234

Figure 4-4: Monthly flows out of River systems S1, S11 & S12A with and without land-use (dams & mines)

The presence of the dams in River system S1, S11 and S12A creates flow variability in especially low flows. An increase in both base and peak flows is also generally observed in the absence of dams/ponds. The same flow behaviour is observed on all the River systems with dams and mines within their respective catchment areas.

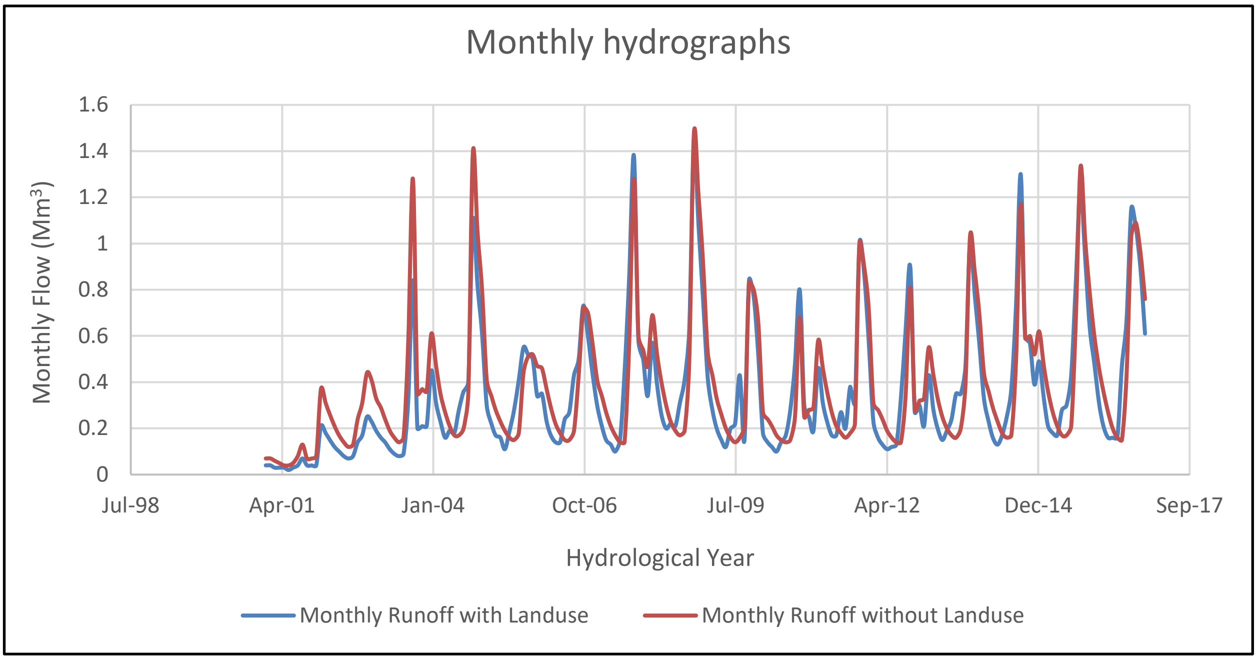


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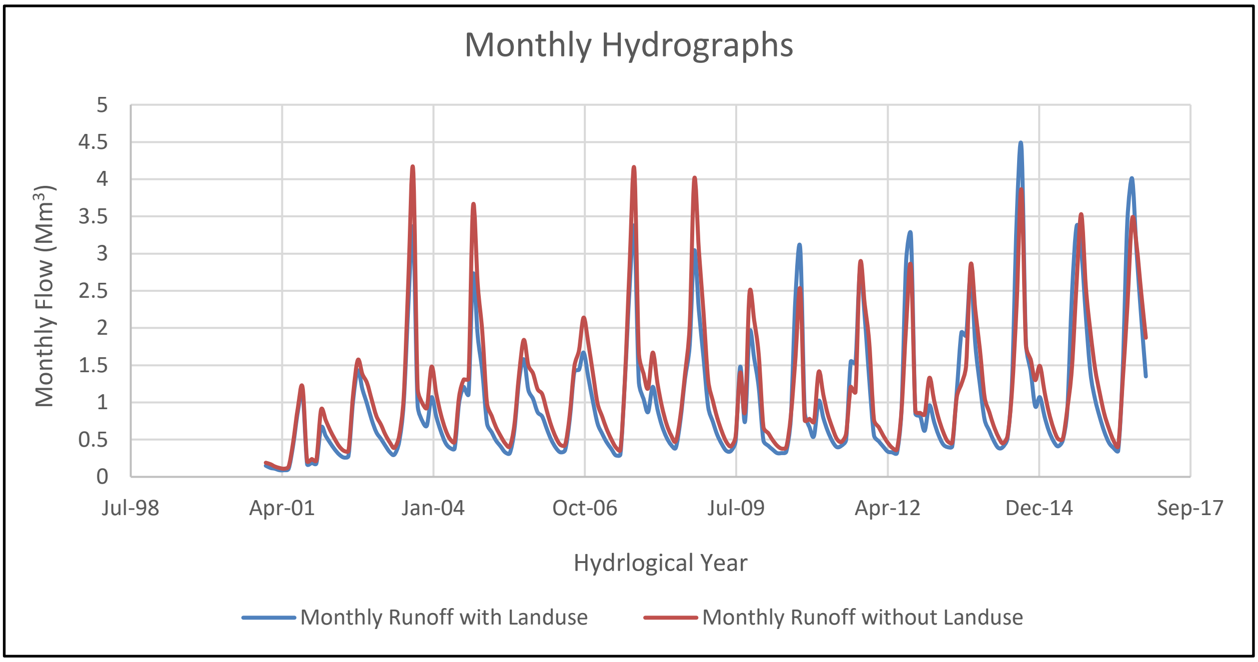
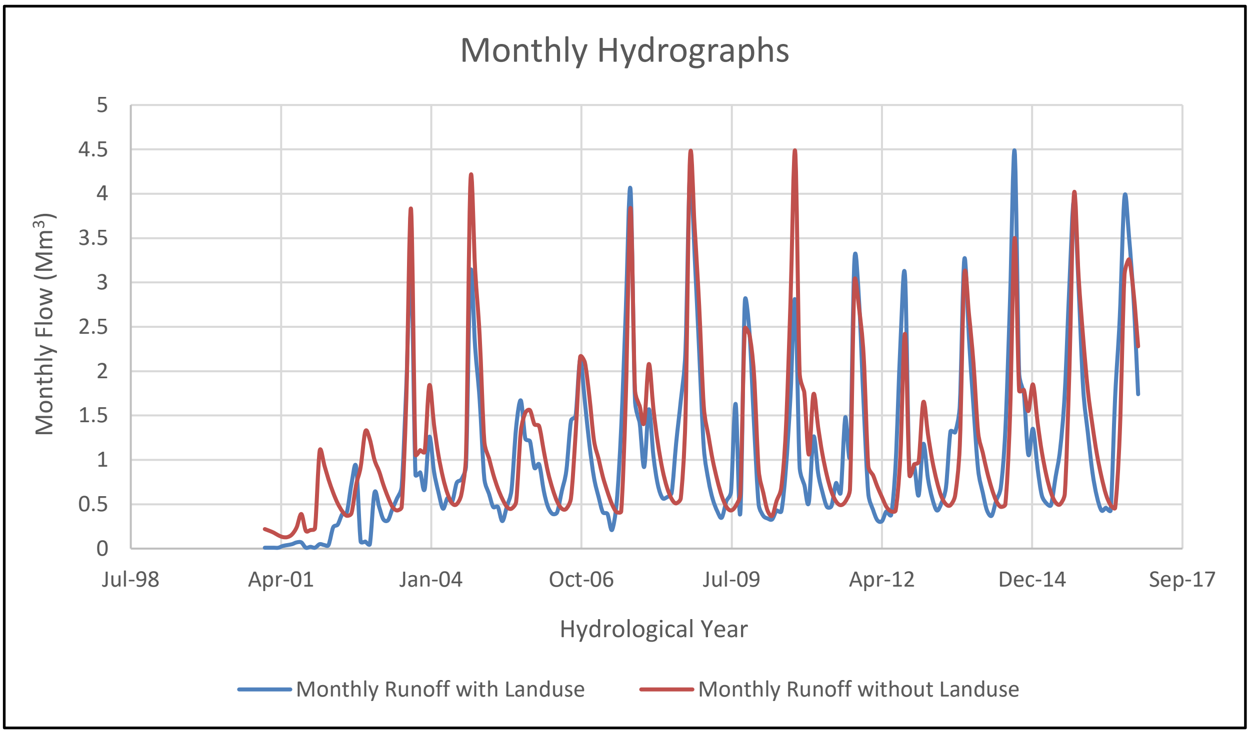
Figure 4-5: Monthly Flows out of River system S2_S5 with and without land-use (dams & mines)



srk consulting	**AREA 1 SURFACE WATER** MONTHLY FLOWS OUT OF S8 WITH AND WITHOUT LAND-USE	Project No. 515234

Figure 4-6: Monthly flows out of S8 with and without land-use (dams & mines)



srk consulting	**AREA 1 SURFACE WATER** MONTHLY FLOWS OUT OF RIVER SYSTEM S10 & S12B WITH AND WITHOUT LAND-USE	Project No. 515234

Figure 4-7: Monthly flows out of River system S10 & S12B with and without land-use (dams & mines)

Table 4-6: Average wet and dry monthly flows in each river system (million m^3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
S1, S11 & S12A: Average Flow	4.29	3.26	2.50	1.92	1.53	1.54	2.63	5.16	8.11	8.39	7.17	5.47	51.97
S1, S11 & S12A: Wet Period Flow	6.45	4.58	3.37	2.52	2.00	2.16	3.93	9.15	14.96	15.55	12.15	8.75	85.57
S1, S11 & S12A: Dry Period Flow	0.58	0.53	0.47	0.41	0.37	0.37	0.84	1.9	3.13	0.53	0.55	0.59	10.27
S2, S3, S4 & S5: Average Flow	0.34	0.24	0.17	0.14	0.14	0.18	0.27	0.44	0.65	0.69	0.59	0.42	4.26
S2, S3, S4 & S5: Wet Period Flow	0.57	0.39	0.26	0.20	0.22	0.28	0.47	0.86	1.38	1.42	1.08	0.76	7.89
S2, S3, S4 & S5: Dry Period Flow	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.04	0.07	0.04	0.04	0.04	0.45
S6: Average Flow	0.13	0.10	0.08	0.06	0.05	0.04	0.04	0.08	0.17	0.21	0.19	0.16	1.32
S6: Wet Period Flow	0.28	0.21	0.16	0.12	0.09	0.07	0.07	0.23	0.51	0.59	0.48	0.37	3.18
S6: Dry Period Flow	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.03	0.03	0.03	0.33
S7: Average Flow	0.18	0.15	0.12	0.09	0.07	0.06	0.06	0.11	0.25	0.29	0.27	0.22	1.86
S7: Wet Period Flow	0.28	0.21	0.16	0.12	0.09	0.07	0.07	0.23	0.51	0.59	0.48	0.37	3.18
S7: Dry Period Flow	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.03	0.03	0.03	0.33
S8: Average Flow	0.80	0.63	0.50	0.39	0.34	0.36	0.84	1.98	2.34	1.83	1.39	1.00	12.41
S8: Wet Period Flow	1.21	0.91	0.69	0.53	0.43	0.52	1.41	3.46	4.44	3.06	2.23	1.61	20.5
S8: Dry Period Flow	0.15	0.12	0.11	0.09	0.09	0.11	0.28	0.88	0.74	0.17	0.19	0.18	3.11
S9: Average inflow	0.07	0.06	0.04	0.03	0.03	0.02	0.02	0.04	0.09	0.11	0.10	0.08	0.70
S9: Wet Period Flow	0.10	0.08	0.06	0.05	0.03	0.03	0.03	0.09	0.19	0.22	0.18	0.14	1.20
S9: Dry Period Flow	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.13
S10 and S12B: Average Flow	0.89	0.62	0.45	0.38	0.41	0.53	0.91	1.63	2.19	2.11	1.72	1.13	12.97
S10 & S12B: Wet Period Flow	1.57	1.04	0.72	0.57	0.58	0.81	1.71	2.78	4.48	4.24	3.3	2.23	24.03
S10 & S12B: Dry Period Flow	0.01	0.01	0.01	0.01	0.03	0.04	0.05	0.07	0.07	0.01	0.02	0.01	0.34

The greatest variation in the flows in the rivers will be the daily changes rather than a monthly total. If the dams are not present the runoff will immediately discharge along the river and will not be retained in the dams. This results in a more variable flow in the rivers than in currently experience below the dams. During the dry season, currently there is little or no flow but this will change as there will be a consistent baseflow in the rivers if the dams/ponds were to be removed.

5 Peak Flows and Flood Peaks

To estimate the influence of a flood on the mine the peak flows in the rivers, were required. The methodology used to estimate the peak flows for the rivers is presented in this section.

5.1 Flood peak characteristics

Catchment areas in and around the Area 1 were identified and these are shown in Figure 5-1. The main catchment (S1) covers a large portion of the site with an estimated size of 258 km^2. It was further divided into 20 sub-catchments. The primary sites included in these sub-catchments are:

- The Lanti operations (dredge and dry mining);
- The Gbeni operation (dry mining);
- Processing operations (floating and land-based concentrators);
- The Gangama operations (dry mining and land-based concentrator);
- MSP; and
- The transport and port facilities at Nitti Port.

In addition, the mine maintains an extensive network of ponds, power-generation facilities, accommodation, offices, a clinic and road infrastructure. The hydro characteristics of each catchment are presented in Table 5-1 below. The same characteristics were used to calculate the peak storm flows.

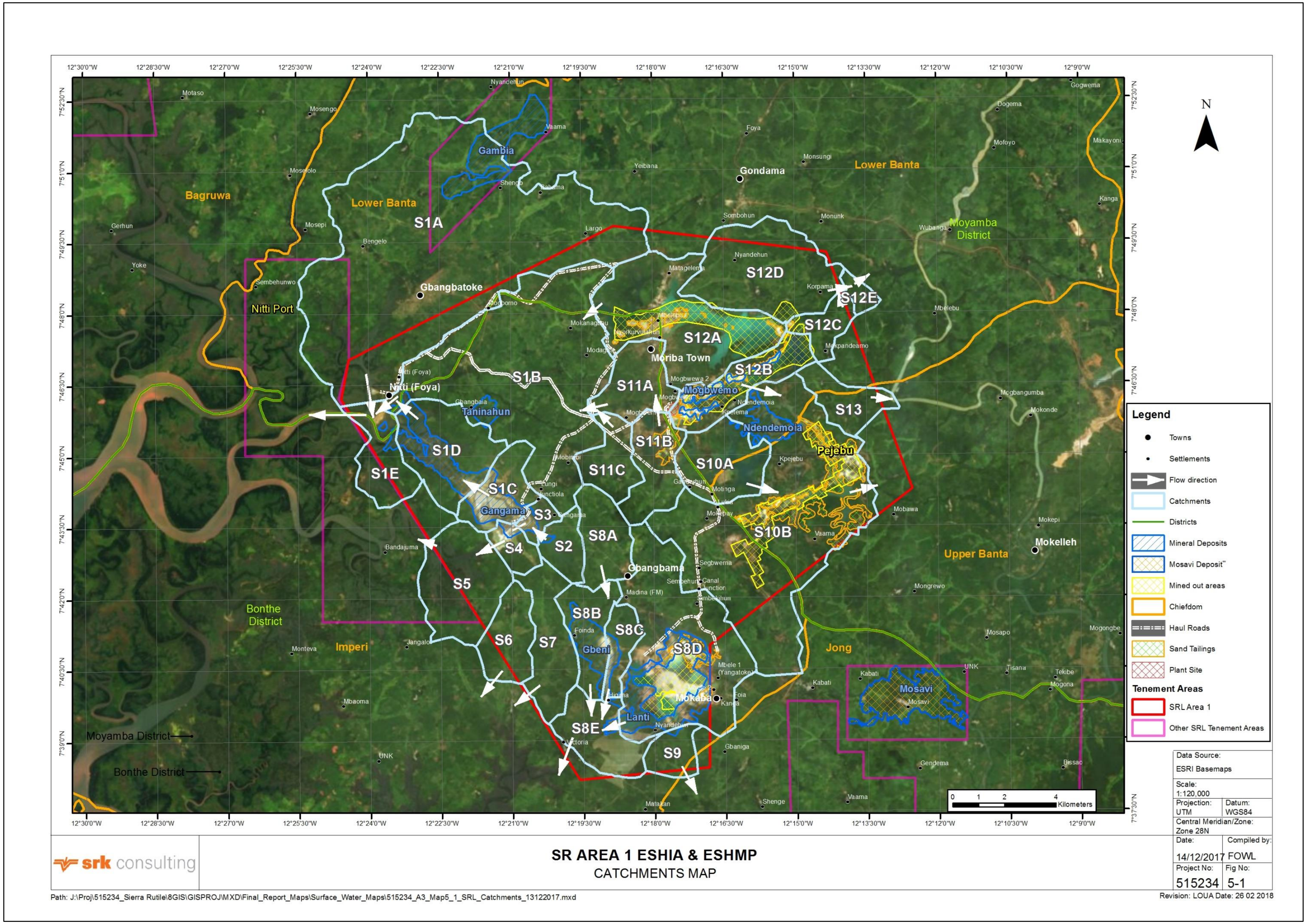


Figure 5-1: Area 1 catchment areas for the flood peaks

Table 5-1: Catchment characteristics for SRL

Catchment Name	Water-course length	10:85 Slope	Area	Tc
	(km)	(m/m)	(km^2)	(hours)
S12A	6	0.0014	21.25	5.0
S11C	3	0.0038	5.29	2.4
S11B	3	0.0024	7.28	2.7
S11A	4	0.0086	12.23	1.7
S1C	3	0.0027	6.13	2.4
S1D	8	0.0010	17.74	6.5
S1B	20	0.0017	72.86	8.4
S1A	16	0.0025	74.86	5.9
S1E (main)	24	0.0029	154.47	7.2
S2	2	0.0031	3.54	1.9
S3	1	0.0574	1.67	0.5
S4	2	0.0298	4.30	0.8
S5	5	0.0042	16.68	2.7
S6	3	0.0104	6.18	1.6
S7	5	0.0038	8.72	3.1
S8A	3	0.0110	6.57	1.6
S8B	9	0.0068	13.05	3.5
S8C	4	0.0036	3.47	2.9
S8D	9	0.0030	27.67	4.3
S8E (main)	14	0.0036	24.13	5.7
S9	4	0.0033	3.32	3.0
S12B	4	0.0030	8.29	3.1
S10A	4	0.0019	8.74	3.0
S10B	8	0.0015	48.29	4.8
S12C	3	0.0100	3.47	1.5
S12D	7	0.0026	20.22	3.8
S12E (main)	7	0.0018	21.52	4.7
S13	4	0.0039	5.03	2.8

Note: The definitions for Table 5-1 are listed below:

- ‘Watercourse length’ is the longest distance from the furthest point of the catchment to the outlet of the catchment;
- ’10:85 slopes’ refer to the slope of the catchment from a point that is 10% from the end point and 85% of the distance to the furthest point; and
- ‘Time of concentration’ (Tc) refers to the length of time it takes for a raindrop to travel from the furthest point of the catchment to the outlet point.

5.2 Estimating peak flows and flood peaks

The peak flows were calculated using the Rational Method (RM) and the Soil Conservation Service (SCS) method, but the RM was adopted for this study. The RM is a well-known and widely-used method. The peak flow equation is contemplated by a runoff coefficient, average rainfall intensity and effective area of the catchment.

The calculated results from the RM are presented in the Table 5-2 below:

Table 5-2: Summary of peak flows (m^3/s)

Catchment Name	Catchment area (km^2)	Flood Peaks (m^3/s)					
		1:2	1:5	1:10	1:20	1:50	1:100
S12A	21.25	104	154	186	243	354	478
S11C	5.29	18	26	33	44	67	90
S11B	7.28	27	39	48	64	97	130
S11A	12.23	42	62	78.77	107	163	217
S1C	6.13	22	32	40	54	82	110
S1D	17.74	82	118	145	189	276	372
S1B	72.86	409	574	705	900	1318	1790
S1A	74.86	407	586	719	944	1384	1865
S1E (main)	154.47	871	1 235	1 516	1 961	2 846	3 856
S2	3.54	10	15	19	26	39	52
S3	1.67	2	4.	6	9	15	20
S4	4.30	9	14	18	26	41	55
S5	16.68	16	59	85	106	142	232
S6	6.18	20	29	37	51.	79	105
S7	8.72	37	53	66	87	130	175
S8A	6.57	21	31	39	54	83	111
S8B	13.05	44	63	78	104	155	207
S8C	3.47	11	15	19	26	39	52
S8D	27.67	108	155	191	251	370	499
S8E (main)	24.13	95	137	169	221	330	446
S9	3.32	10	15	19.20	25	38	51
S12B	8.29	27	39	49	65	97	131
S10A	8.74	28	40	50	67	100	135
S10B	48.29	180	258	317	417	625	847
S12C	3.47	8	13	16	22	34	46
S12D	20.22	71	101	125	165	244	328
S12E (main)	21.52	79	114	140	184	272	366
S13	5.03	15	22	28	37	56	75

6 Floodline Determination

In order to ensure that the mine infrastructure is not impacted on by the rivers, a floodline analysis was conducted for the rivers that could potentially impact the mine workings. Floodline determination for the watercourses in the historical mining areas were not undertaken as the river flow paths have been altered and are now predominantly dams. Floodlines in the dam areas are controlled by the spillway dimensions and these dams occupy the bulk of these catchments and thus negates any significant flooding potential. The floods into the dams are significantly attenuated and hence floodlines for these dam areas have been excluded from this study.

6.1 Floodline characteristics

6.1.1 Site location

Six catchments have been identified in Area 1: S1A, S1B, S1D, S8B, S8C and S8E where floodlines were undertaken. Some of the catchments indicated in Table 4-2 are within these six identified catchments. More detail is provided in the points that follow:

- S1A – situated 9.4 km west of the MSP site and 6.84 km north of the Gangama operations;
- S1B – situated 2.8 km north west of the MSP site and 3.28 km north of the Gamgama operations;
- S1D – situated 7.2 km east of the MSP site and 1.85 km north of the Gangama operations;
- S8B – catchment within the Gbeni pit area;
- S8C – incorporates part of the Gbeni pit area as well as the upstream area; and
- S8E – area downstream of the Lanti operations.

The catchments are shown in Figure 6-1 and Figure 6-2 below.

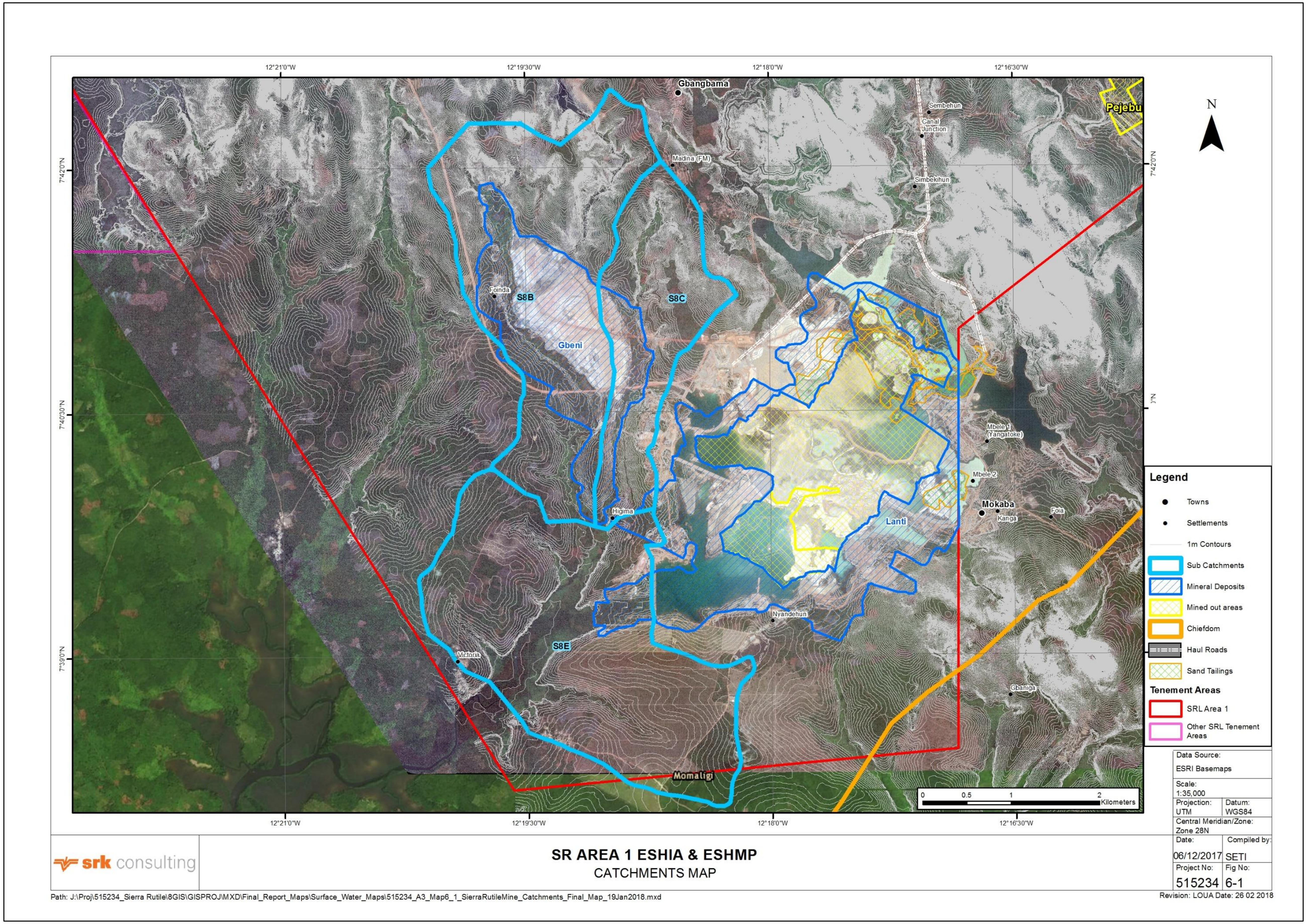


Figure 6-1: Area 1 catchments map for sub-catchments S8B, S8C and S8E

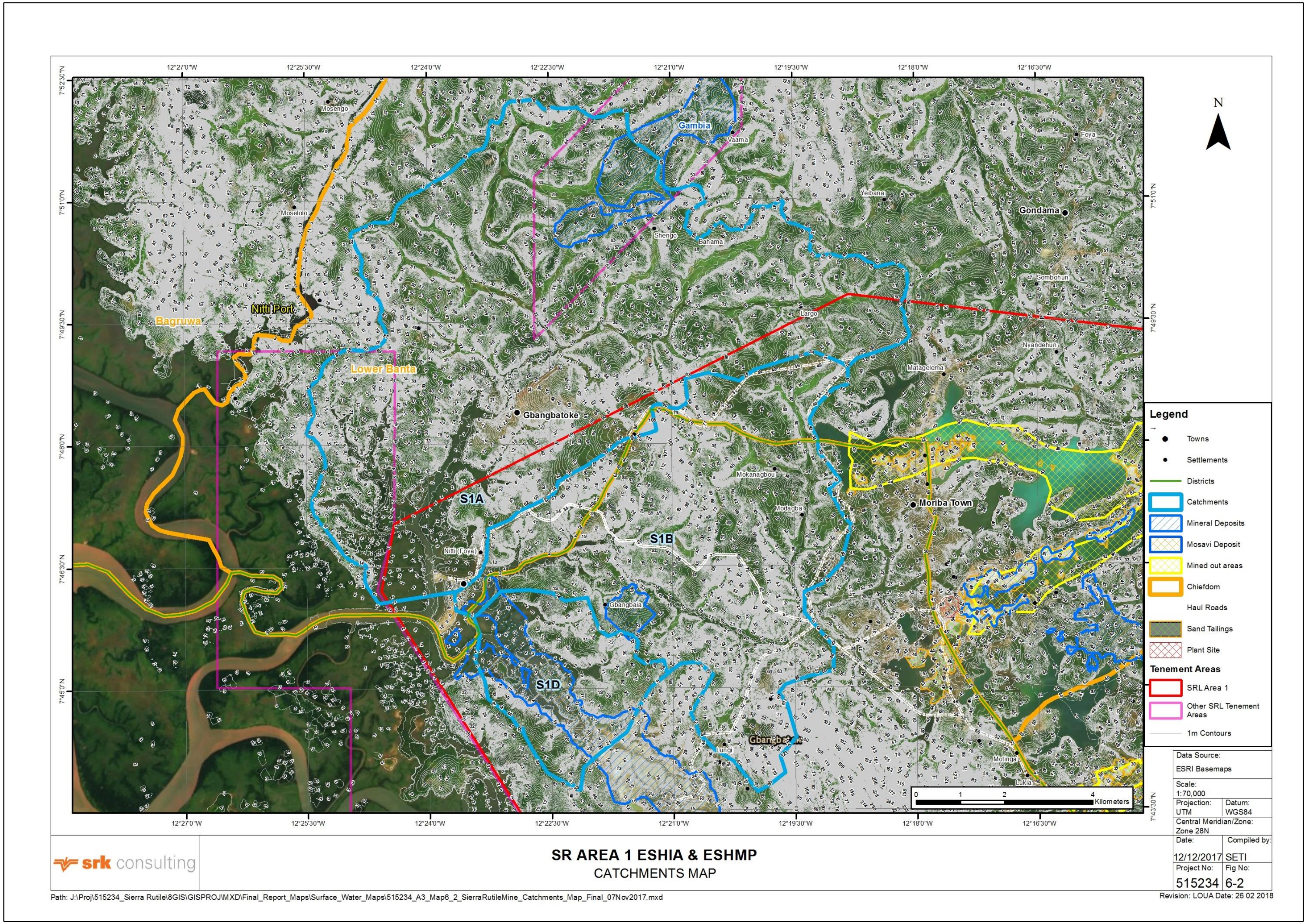


Figure 6-2: Area 1 catchments map for sub-catchments S1A, S1B and S1D

6.1.2 Catchment data

The catchment data was collected from aerial photo maps, Google Images and the contour map supplied by SRL. Refer to Figure 6-1 and Figure 6-2 above. The 1:50 year and 1:100 year return period flood peaks as obtained from the previous section.

6.2 Floodline modelling and estimation

6.2.1 Storm rainfall

The combined 20 m and 1 m contour survey was converted to a Digital Terrain Model (DTM) and entered into HEC-RAS (Version 5.0.1). The HEC-RAS model requires boundary river flow conditions, detailed channel morphology and site-specific hydrological data to reckon one-dimensional hydraulic calculations for a specific river network.

Floodlines were modelled using the natural cross sections along the study area. The input data included:

- Cross section from 1 m LIDAR contours available from the survey data;
- ‘Roughness’ of the watercourse (observed at site visit). Manning coefficient was 0.035; and
- The peak flow was calculated using the Rational Method and SCS methods.

The primary parameters of the HEC-RAS model are presented in Table 6-1 below.

Table 6-1: HEC-RAS model main parameters

Parameter	Average Value/Selection	Reason
Manning coefficient	0.035 (main flow channel)	Defined channel with little vegetation to thick vegetation
Boundary conditions	Normal flow depth	Control structures present
Flow regime	Mixed flow	Slope and cross section changes requiring super and sub-critical flow regimes

The cross sections were defined using the River Referencing System (RRS). Using Arc Map, geometrical and spatial data was imported to generate the floodline extent. The modelling results are presented in Appendix B and in Figure 6-3 and Figure 6-4.

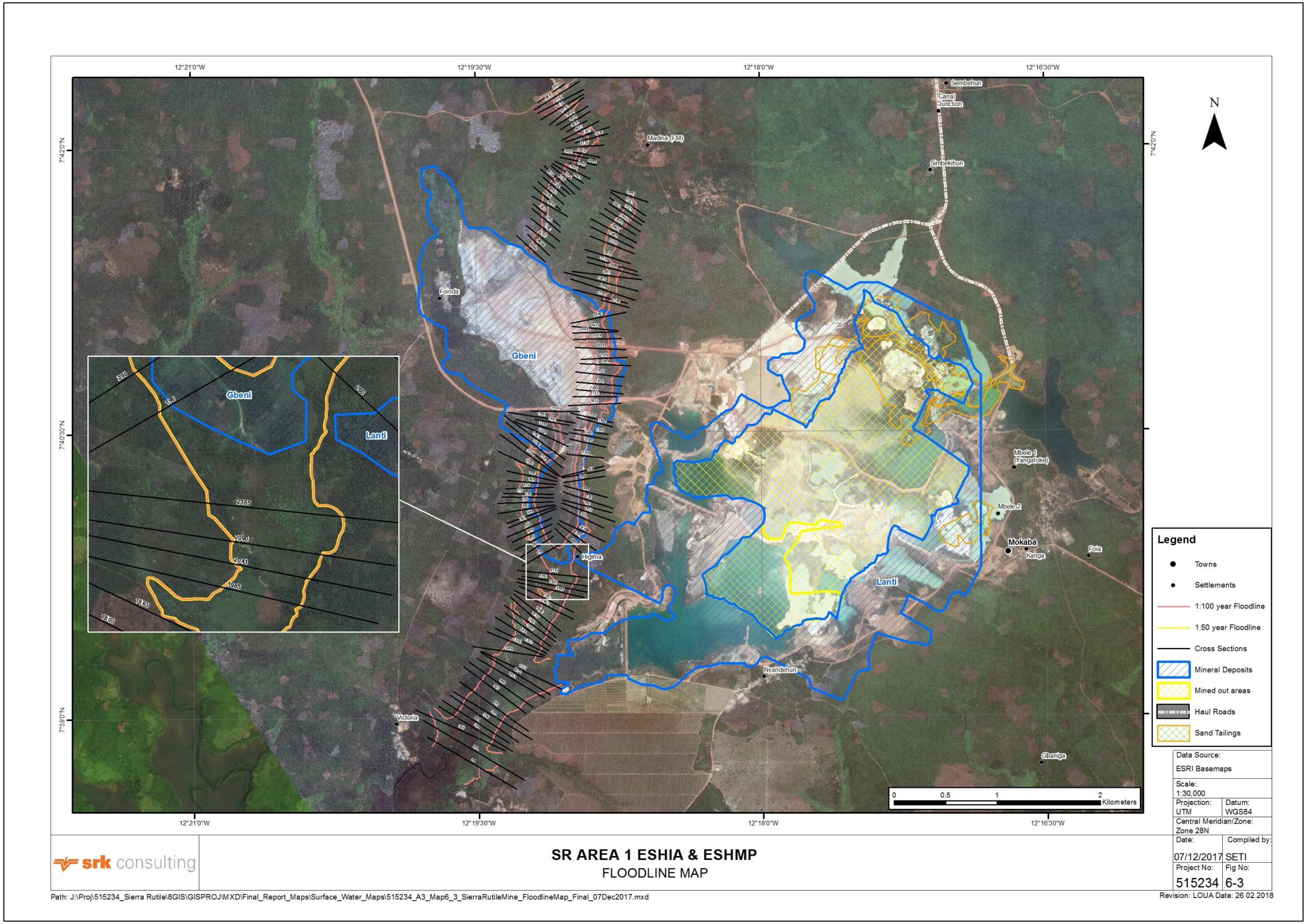


Figure 6-3: Floodline map for the Gbeni and downstream of L4 Lanti operations

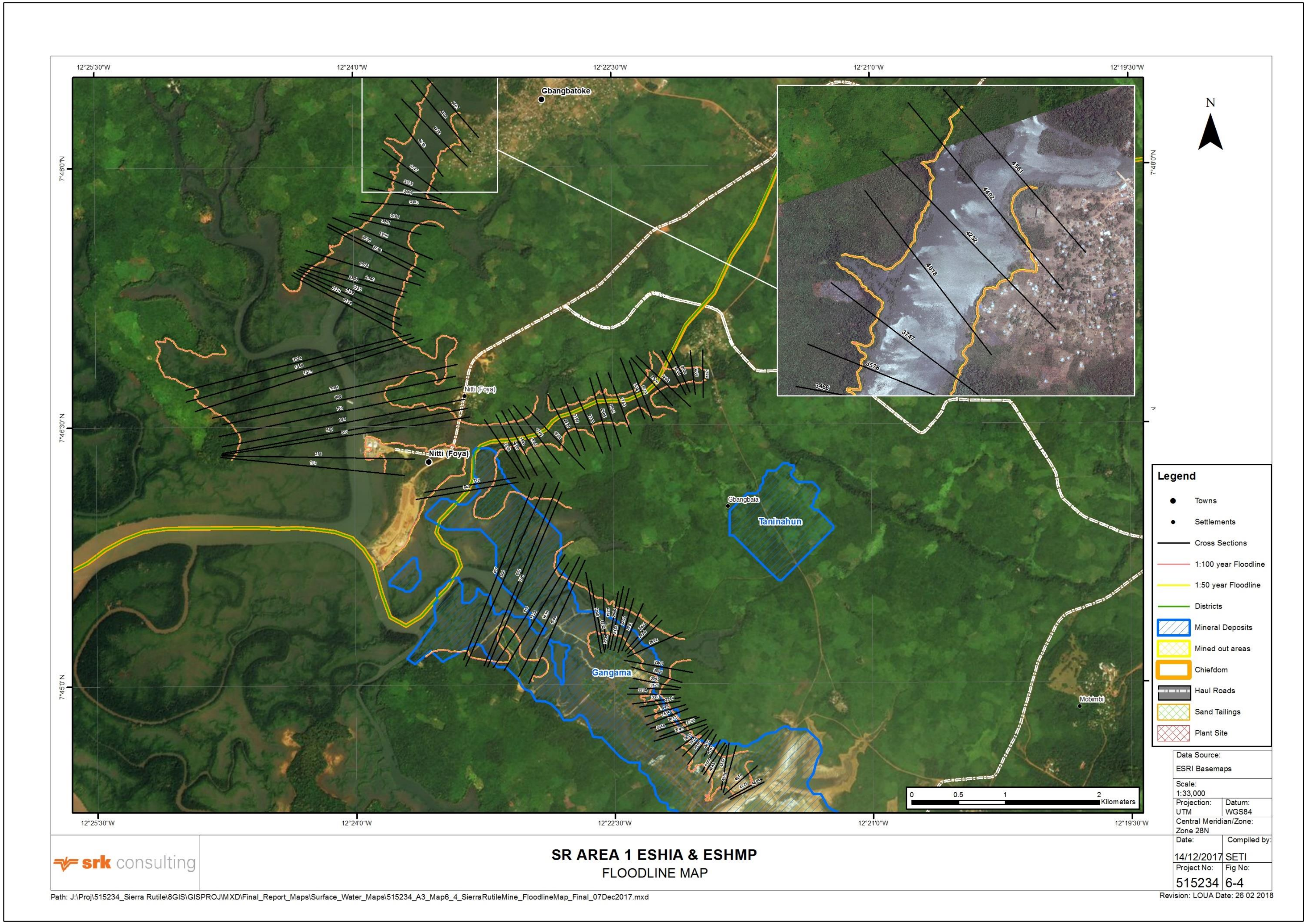


Figure 6-4: Floodline map for the Gangama operations and the Nitti Port

7 Stormwater Management

The information contained in this section was sourced from discussions with mine management and SRK's visual inspections during the site visits.

The areas where storm water management systems have been developed are as follows:

- MSP;
- Dry Mining Plant 1 (DM 1), located at the Lanti operation;
- Dry Mining Plant 2 (DM 2), located at the Gangama operation;
- Gbeni operation; and
- Nitti Port.

Proposed developments at SRL include, but are not limited to:

- Stormwater diversion berms and channels to redirect natural water away from new mining areas;
- The natural water system will allow for natural water holding dams and attenuation dams in the low-lying topographical areas;
- Mine impacted water collection berms to redirect water to the appropriate containment facility (dredging ponds); and
- Construction of silt traps to collect sediment before discharge.

Due to the high level of rainfall in Sierra Leone, a robust stormwater system is essential for the sustainability of the mine. The existing and proposed systems are considered in the sections below.

7.1 Current stormwater management

The natural water system at SRL is currently managed as described below.

7.1.1 Mineral Separation Plant (MSP)

The MSP is situated on a high lying area and therefore does not have or require any natural water management system to be in place. The non-impacted runoff flows as indicated in Figure 7-1, while the remainder of the runoff from site, flows towards the Mogbwemo Dredge Pond. The Mogbwemo Dredge Pond overflows into the Pejebu Dredge Pond and from there it overflows into the Tikote Stream.

7.1.2 Dry Mining Plant 1 (DM 1 - Lanti Operation)

The DM 1 Plant is located in the north-eastern side of the Lanti operation. The haul roads serve as stormwater runoff conduits (see Figure 7-2). Apart from the conduits, there is no natural water infrastructure at this location (see Figure 7-3).

Consequently, the stormwater runoff naturally flows towards the Lanti Containment Pond (CP 8). Runoff that reports into CP8B overflows via two culvert spillways into GBCD canal. Runoff that reports into CP8A flows out into an active pond via its own spillway and consequently through L4 Dam spillway. Discharge from the dam flows to the L4 Dam and is then subsequently discharged into the Lanti Stream.

The C3 Dam is a natural clean water holding dam on the eastern side of the Lanti operation. It serves two functions: firstly, to maintain water supply to the MSP and the dredging pond during dry periods and secondly, to mitigate the impacts of potential flooding at the Lanti operation.

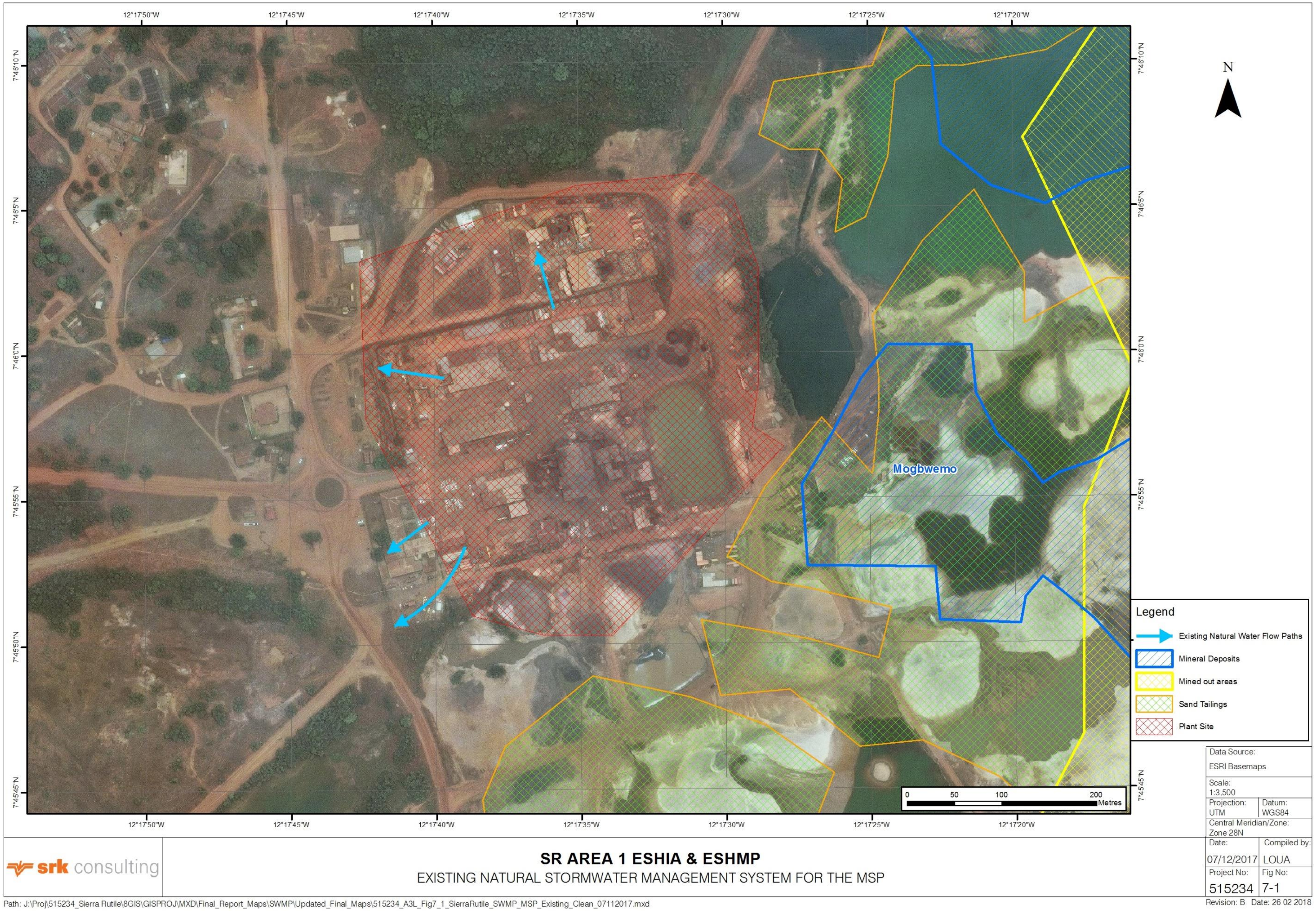


Figure 7-1: Existing natural stormwater management system at SRL mine for the MSP

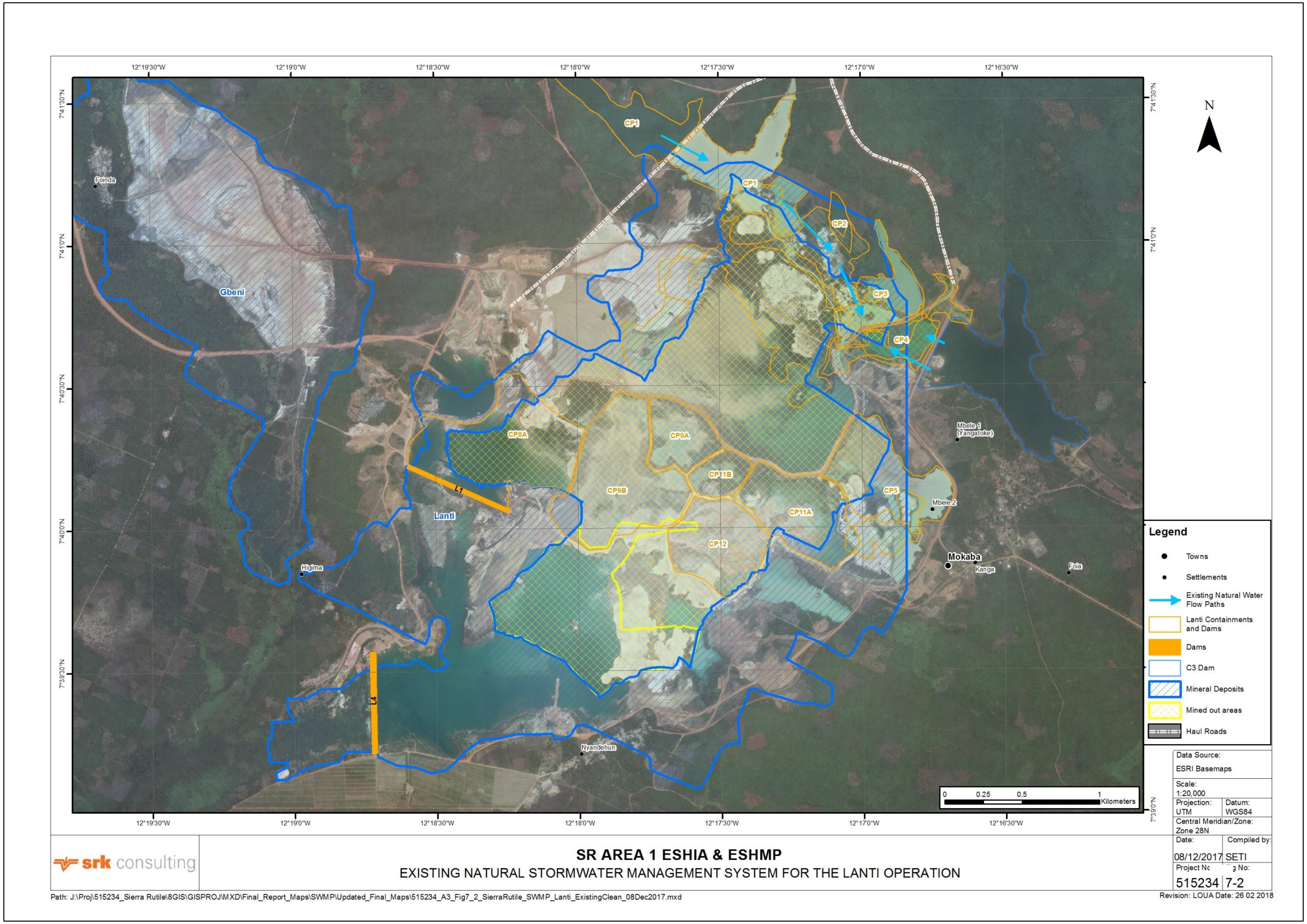


Figure 7-2: Existing natural stormwater management system at the Lanti operation

srk consulting	**AREA 1 SURFACE WATER** LANTI OPERATION NATURAL WATER SYSTEM – DISCHARGE POINT AT L4 DAM WALL	Project No. 515234

Figure 7-3: Photographs of the Lanti operation natural water system – Discharge point at L4 dam wall

7.1.3 Dry Mining Plant 2 (DM 2 - Gangama Operation)

The DM 2 Plant is located north west of the G7 Dam and north east of the G6 Dam. The plant is located on an elevated haul road which also serves as a retaining wall for the G4, G6 and G7 Dams (see Figure 7-4). With the elevated plant, there is no need for stormwater diversion infrastructure (see Figure 7-5).

There is no other natural water infrastructure at this location.

The haul roads serve as stormwater runoff conduits around the plant area. The stormwater runoff naturally flows towards the G4, G6 or G7 Dams or, towards the unmined mineral resource areas in the north-west. Runoff that flows into these Dams either discharges through the spillway at the G4 Dam wall.

The G5 Dam is a raw water holding dam to the south east of the DM 2 Plant. It serves two functions: firstly, to maintain water supply to the Plant and the dredging pond during dry periods and secondly, to mitigate the impacts of potential flooding at the Gangama operation.

There are a number of holding dams located on the eastern side of the new mining area. These dams are connected by channels to prevent the runoff from entering the mine works.

Recommended modifications to the natural water system are discussed in Section 7.3.

Figure 7-4: Existing natural stormwater management system at Gangama operation

srk consulting	**AREA 1 SURFACE WATER** GANGAMA OPERATION NATURAL WATER SYSTEM – G5 DAM AND DISCHARGE POINT AT BREACHED G1 DAM WALL	Project No. 515234

Figure 7-5: Photographs of the Gangama operation natural water system showing the G5 Dam (left) and the discharge point at the breached G1 Dam wall (right)

7.1.4 Gbeni Operation

The Gbeni operation is a relatively new, but active mining area. The natural water diversion drain (Gbeni West Trench) extends upslope for most of the western edge of the Gbeni deposit (see Figure 7-6). There is also a drain that feeds into the Gbeni West Trench, draining the upslope catchments and GB3 Dam and crosses the deposit east to west.

This area is often flooded and requires improved drainage infrastructure in the near future (see Figure 7-7)

There are also smaller channels draining the middle section of the deposit. The runoff flows towards the south and is finally discharged into Teso River which eventually flows out into the sea. This stream is influenced by the tide.

Due to the impact of flooding on mining operations, temporary infrastructure has been erected to drain the eastern areas. The drains converge with the Gbeni West Trench to the south of the deposit.

7.1.5 Nitti Port

The Nitti Port is located along the banks of a large estuarine river and has been constructed at a level higher than the tidal fluctuations and situated outside the 1:100 year floodline.

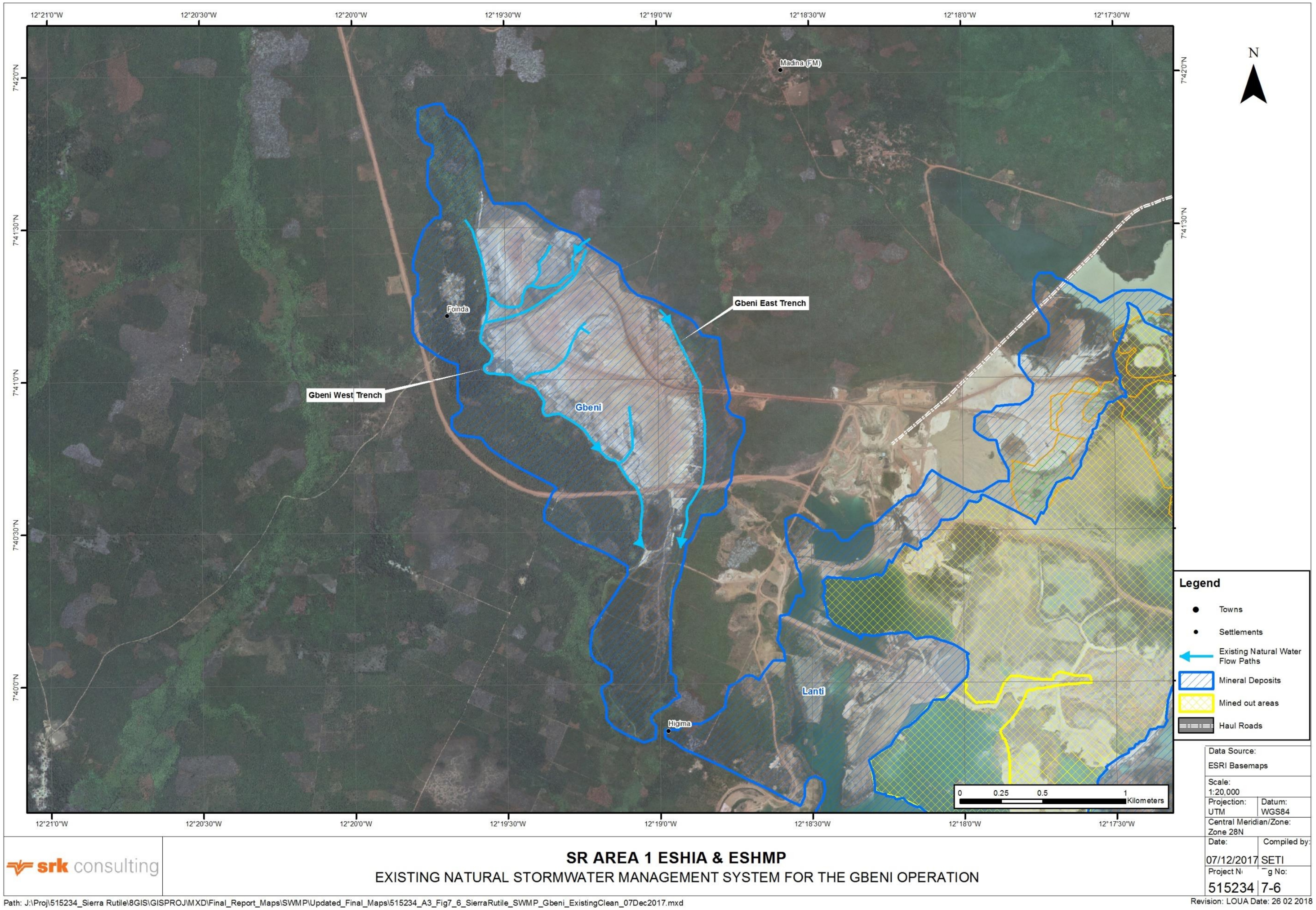


Figure 7-6: Existing natural stormwater management system at the Gbeni operation

srk consulting	**AREA 1 SURFACE WATER** GBENI OPERATION NATURAL WATER SYSTEM – GBENI WEST TRENCH	Project No. 515234

Figure 7-7: Photographs of the Gbeni operation natural water system at the Gbeni West Trench

7.2 Mine impacted stormwater management

The mine impacted stormwater system at Area 1 is described in the subsections that follow.

The water quality of the discharge should continue to be monitored and only released into the environment if the quality meets the Water Quality Standards of Sierra Leone legislation. This is expanded on in Section 9.

7.2.1 Mineral Separation Plant

The MSP is located on a high-lying area and does not require any additional mine impacted water management infrastructure (see Figure 7-8). There are a few internal mine impacted stormwater drains that assist in draining the water from a number of sources towards the greater Mogbwemo Dredge Pond (see Figure 7-9).

The Mogbwemo Dredge Pond spills into the Pejebu Dredge Pond from where the water is naturally discharged.

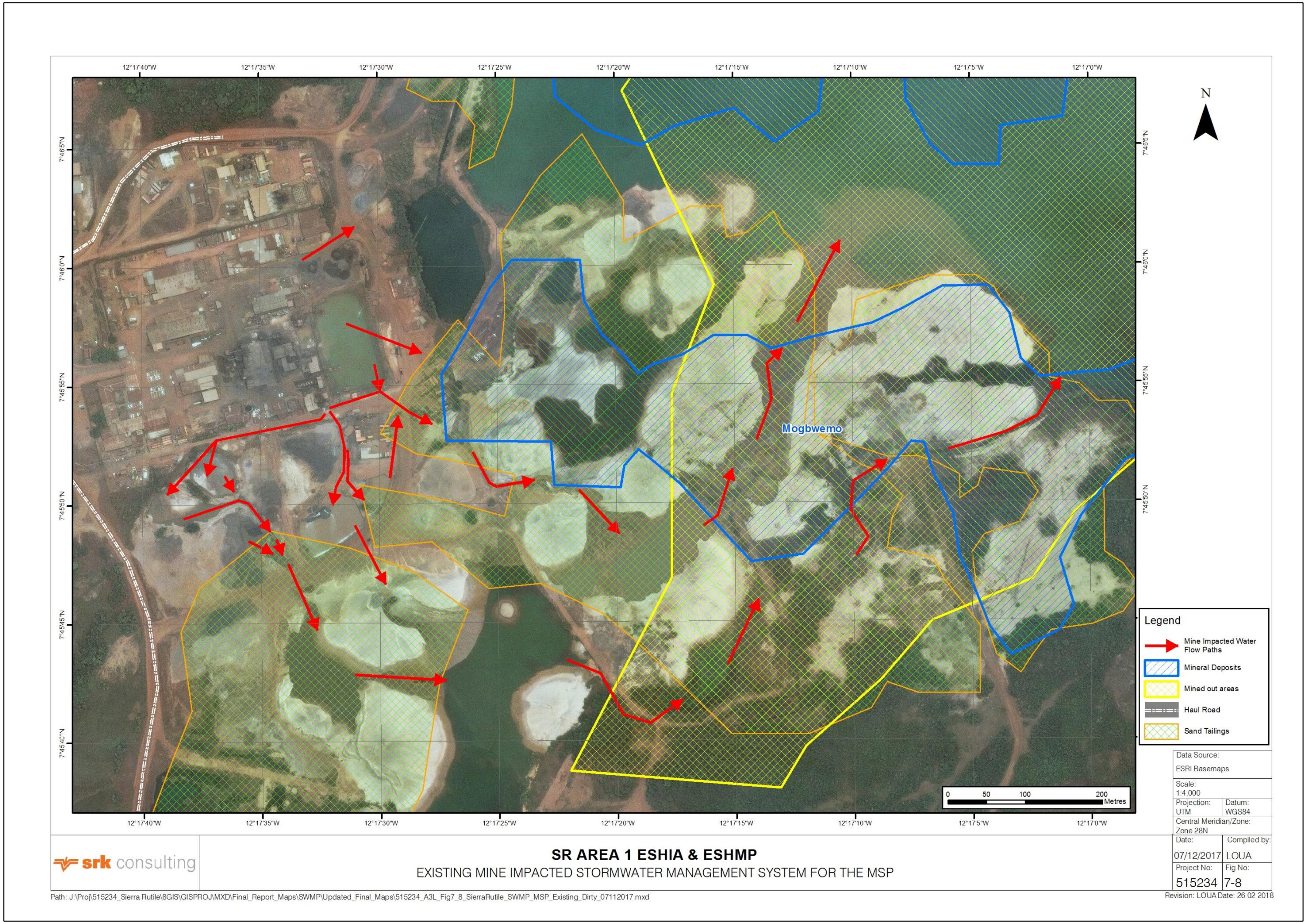


Figure 7-8: Existing mine impacted stormwater management system at the MSP

srk consulting

AREA 1 SURFACE WATER
CURRENT MSP MINE IMPACTED WATER SYSTEM

Project No.
515234

Figure 7-9: Photographs of the current MSP mine impacted water system with the mine impacted areas, Lake Grey and the point where mine impacted water flows into the Mogbwemo Pond

7.2.2 Dry Mining Plant 1 (DM 1 - Lanti Operation)

The DM 1 Plant is located on the north-eastern side of the Lanti operation. The haul roads serve as stormwater runoff conduits for the area surrounding the Plant and containment ponds (see Figure 7-10). Guided by berms, river diversions and channels, the water flows along the eastern perimeter to the L4 Dam (see Figure 7-11)

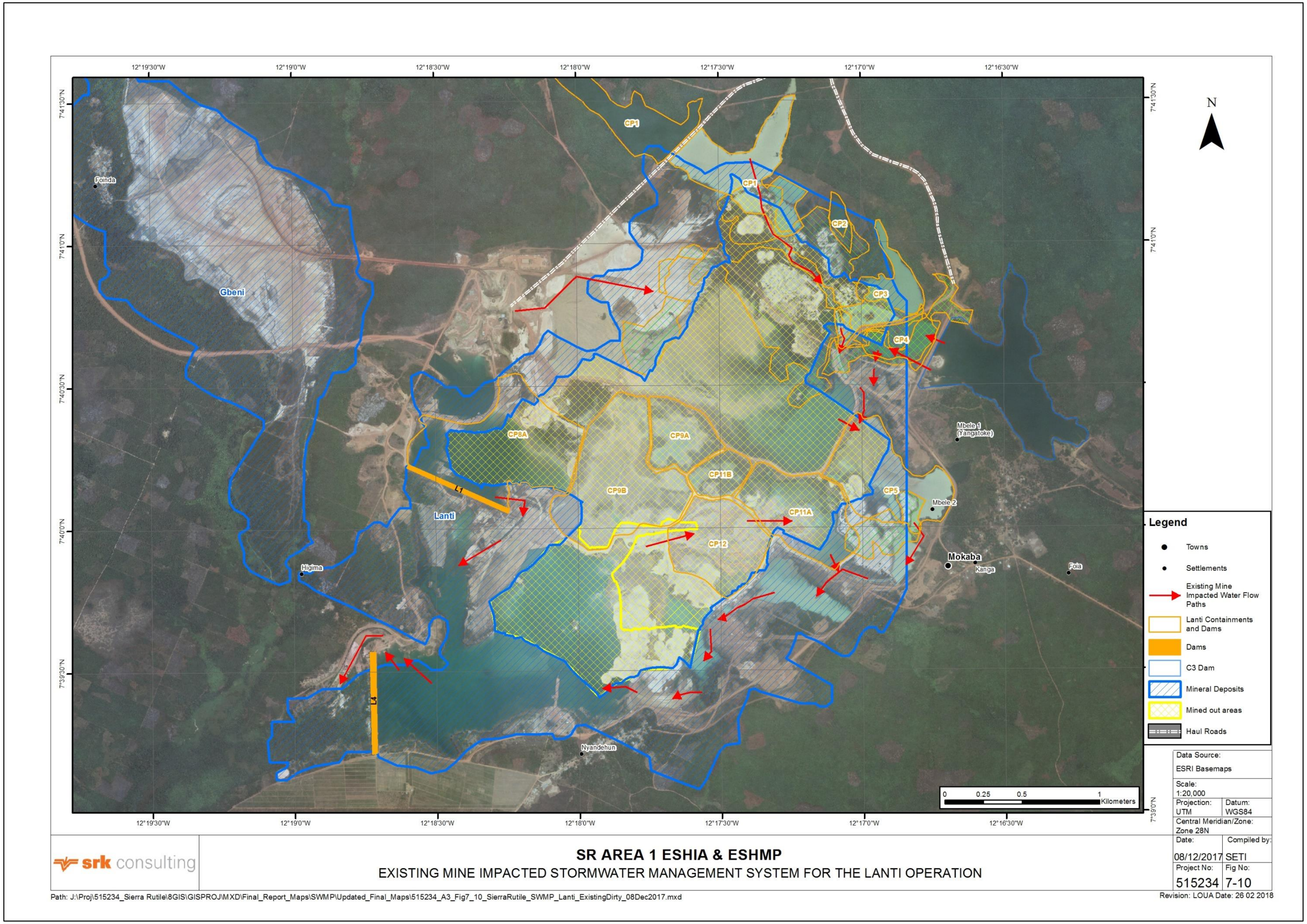
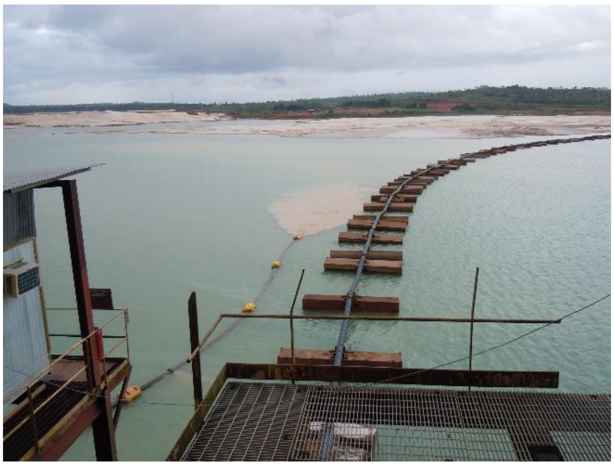


Figure 7-10: Existing mine impacted stormwater management system at the Lanti operation



srk consulting	**AREA 1 SURFACE WATER** EXISTING LANTI MINE IMPACTED WATER SYSTEM	Project No. 515234

Figure 7-11: Photographs of the existing Lanti mine impacted water system at the outlet near CP6 into the channel flowing to L4 Dam (left) and at the Barge showing the tailings (right)

7.2.3 Dry Mining Plant 2 (DM 2 - Gangama Operation)

The DM 2 Plant is located on an elevated haul road that also serves as a retaining wall for the G4, G6 and G7 Dam walls (see Figure 7-12). With the Plant elevated above the surrounding topography, there is no need for mine impacted water infrastructure (see Figure 7-13).

The haul roads serve as the stormwater runoff conduits for the area surrounding the Plant.

Below the G6 Dam wall, a containment pond receives process water from the Plant to spill into the new mining area. There are overflow points at the G4 Dam and the G7 Dam, both discharging water.

To decrease the high level of water in the G6 Dam or another upstream dam, the overflow point is assisted by a pump located at the G4 Dam spillway. The other overflow point is located at the G7 Dam. The flow is directed downslope to the new mining area to the north west of the plant. This culvert is part of a drainage system to distribute stormwater towards the G1 Dam in the north east and into the estuary. The dam has been breached to accommodate dry mining operations.

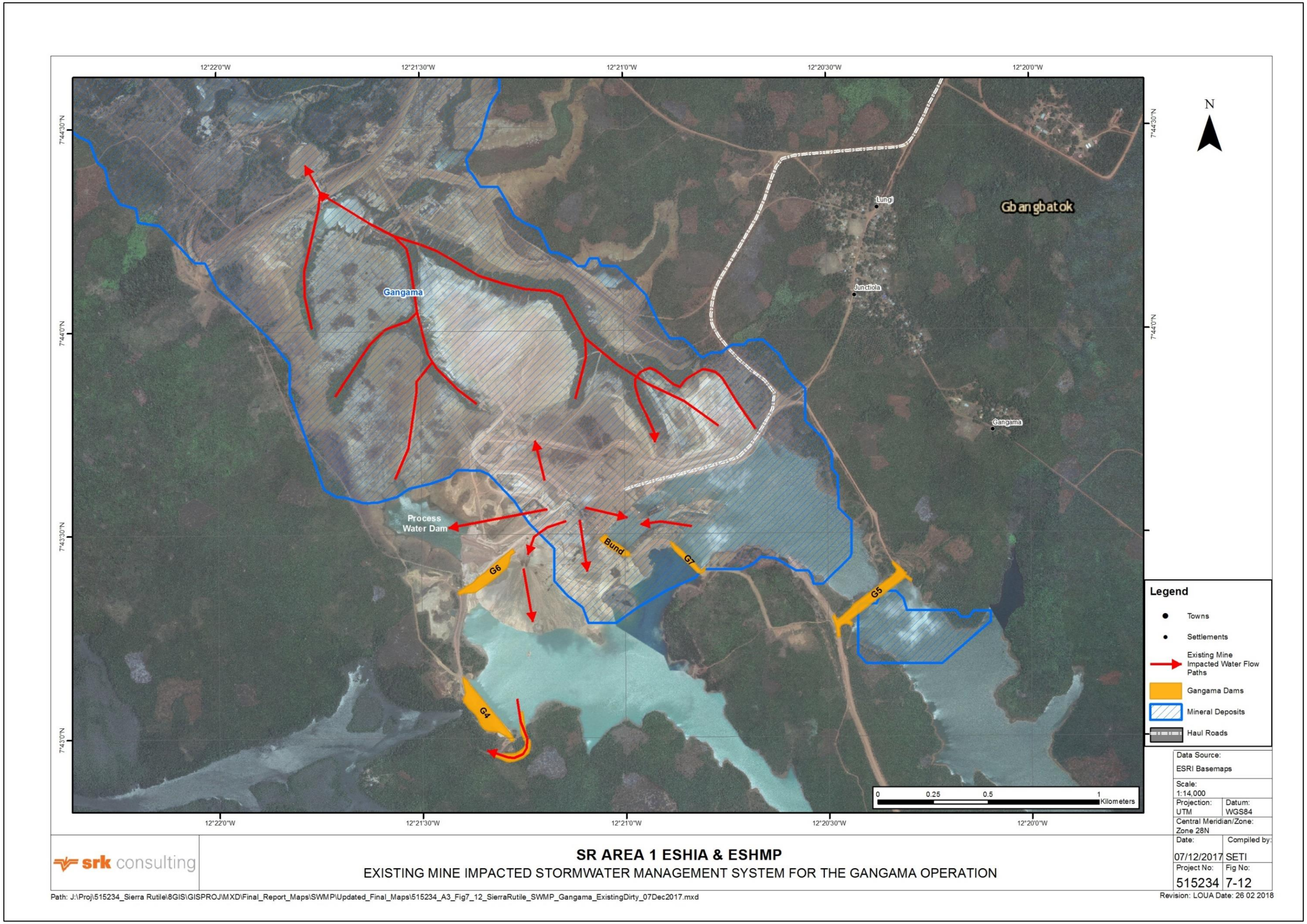


Figure 7-12: Existing mine impacted stormwater management system at the Gangama operation

srk consulting	**AREA 1 SURFACE WATER** GANGAMA OPERATION MINE IMPACTED WATER SYSTEM	Project No. 515234

Figure 7-13: Photographs of the Gangama operation mine impacted water system

7.2.4 Gbeni Operation

The Gbeni operation is a relatively new, but active mining area. Mine impacted stormwater in this area is mostly confined to the pit (see Figure 7-14). Ponding in the pit area enters the natural water system as discussed in Section 7.1.4.

This area is often flooded and requires improved drainage infrastructure in the near future (see Figure 7-15).

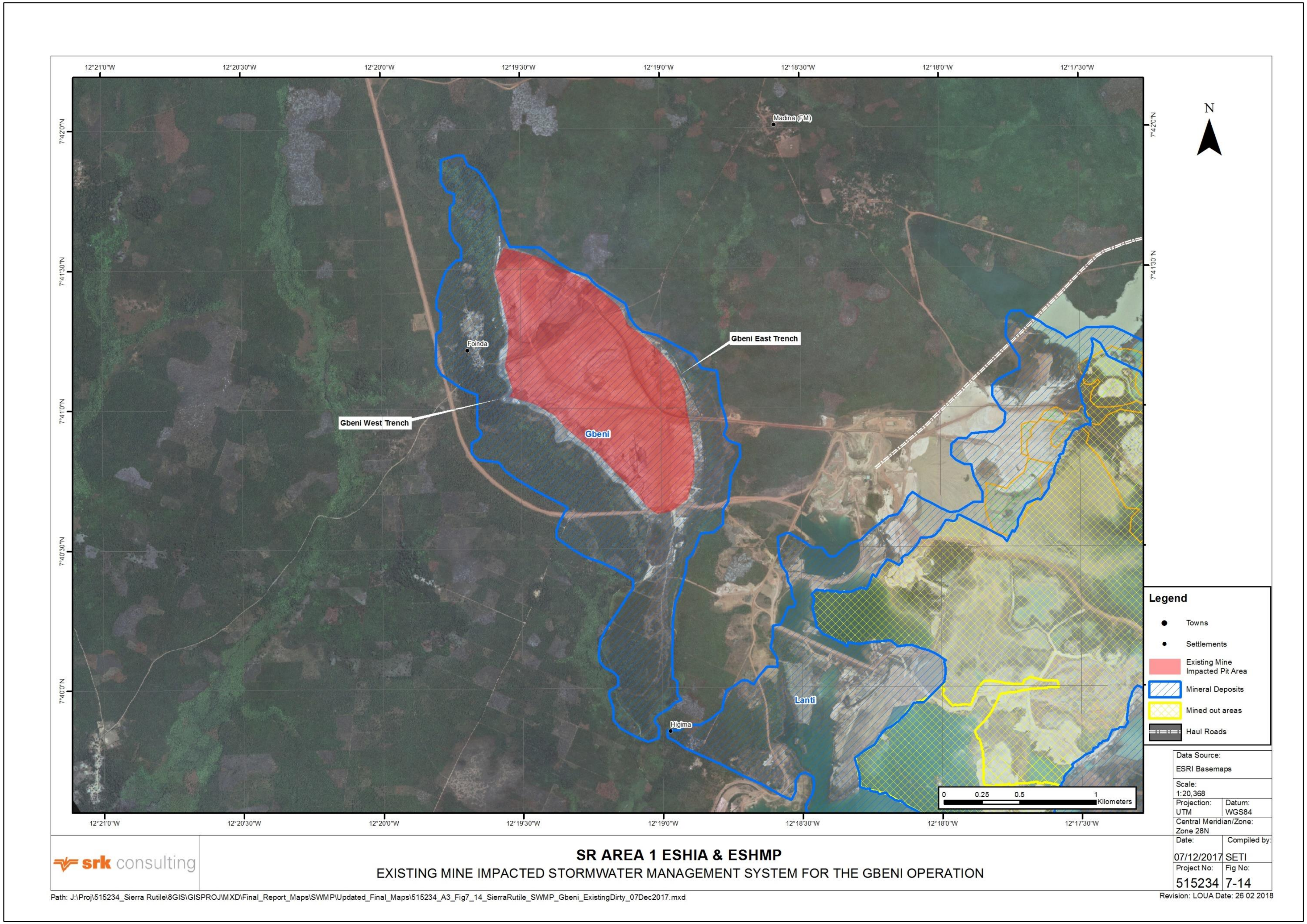


Figure 7-14: Existing mine impacted stormwater management system at the Gbeni Operation

srk consulting	**AREA 1 SURFACE WATER** GBENI OPERATION MINE IMPACTED AREA AND PIT	Project No. 515234

Figure 7-15: Photographs of the Gbeni operation mine impacted area and pit

The existing stormwater management system at Nitti Port is shown in Figure 7-16. A channel flows from the entrance gate along the southern boundary until halfway to the estuary and discharges into the mangrove swamps. There is no silt trap in this location.

Similarly, there is a channel flowing from the entrance gate along the northern boundary until halfway to the estuary. The channel flows into the northern silt trap and discharged into the mangrove swamps. A channel flowing from the west also discharges into the northern silt trap.

There are soil bund walls around the fuel tanks however the based are unlined, and should the tanks leak or spill, it is expected that the fuel will seep into the soil.

Photographs of the existing mine impacted stormwater management system are shown in Figure 7-17.

Figure 7-16: Existing mine impacted stormwater management system at Nitti Port

srk consulting	**AREA 1 SURFACE WATER** CURRENT NITTI PORT MINE IMPACTED WATER SYSTEM	Project No. 515234

Figure 7-17: Photographs of the current Nitti Port mine impacted water system showing the mine impacted water collection drains and the earthen berms around the fuel storage tanks

7.3 Proposed stormwater management plan

Drafted according to the life of mine and present expansion, the Stormwater Management Plan (SWMP) has been compiled for each of the mining areas, Nitti Port and the MSP, to be phased in over the medium to long term.

The desired management plan is discussed further in this section.

7.3.1 SWMP objectives

The objectives of the SWMP are:

- To provide a practical and executable plan for the management of stormwater on site;
- To provide effective management and separation of natural and mine impacted water; and
- To facilitate compliance with Sierra Leone legislative, EIA operating licence and GIIP standards.

Water management measures include the diversion of natural runoff upstream of the mining activities, as well as limiting mine impacted runoff areas to the designated facilities (pollution control dams / in-pit pumping). There is currently no specific storm recurrence interval required to separate natural and mine impacted water in Sierra Leone, and therefore the design criteria used is described below.

7.3.2 Design criteria

1:50 year peak flow event has been used for channel sizing. The IFC standard for dams is the 1:100 year Return Period and the Maximum Probable Flood for tailings dams.

7.3.3 Mineral Separation Plant

There are no proposed changes to the MSP SWMP. Although the oil trap at the power plant needs to be repaired and the other remaining oil traps need to be maintained.

7.3.4 Dry Mining Plant 1 (DM 1 - Lanti Operation)

There are no proposed changes to the DM 1 Plant SWMP. Figure 7-18 shows the natural water flows at Lanti although there are no changes to the stormwater system. The figure was included to aid in the understanding of the stormwater system at Lanti.

7.3.5 Dry Mining Plant 2 (DM 2 - Gangama Operation)

The Plant is located on an elevated haul road that also serves as a retaining wall for the G4, G6 and G7 dam walls. With the elevation (primarily dams surrounding), there is no need for additional mine impacted water infrastructure. The runoff is naturally directed towards the G4, G6 and G7 Dams or, towards the unmined mineral resource areas to the North West (see Figure 7-19).

Although there is a temporary pump installed at G4 Dam, the spillway at the dam wall allows water to flow into the environment. A silt trap is a proposed measure to limit the amount of sediment flowing into the environment upon discharge.

The G5 Dam is a raw water holding dam to the south east of the DM2 Plant. There are a number of stormwater dams located on the eastern side of the new mining area. These are connected by channels preventing natural stormwater runoff entering the workings. The proposed clean stormwater system has sized these channels as well as the holding dams for the 1:50 year return period storm. This is presented in Section 7.5.

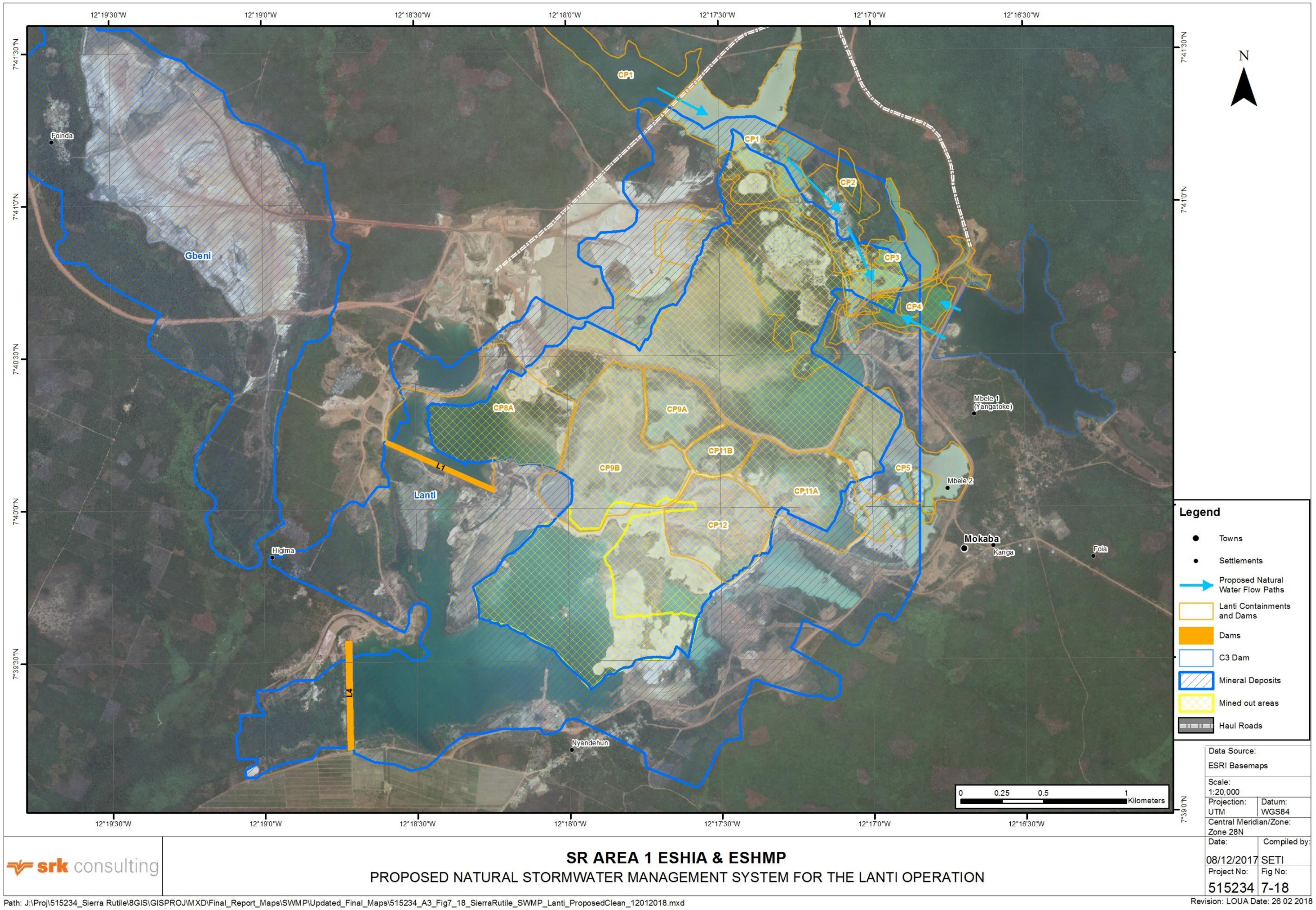


Figure 7-18: Proposed natural stormwater management system at the Lanti operation

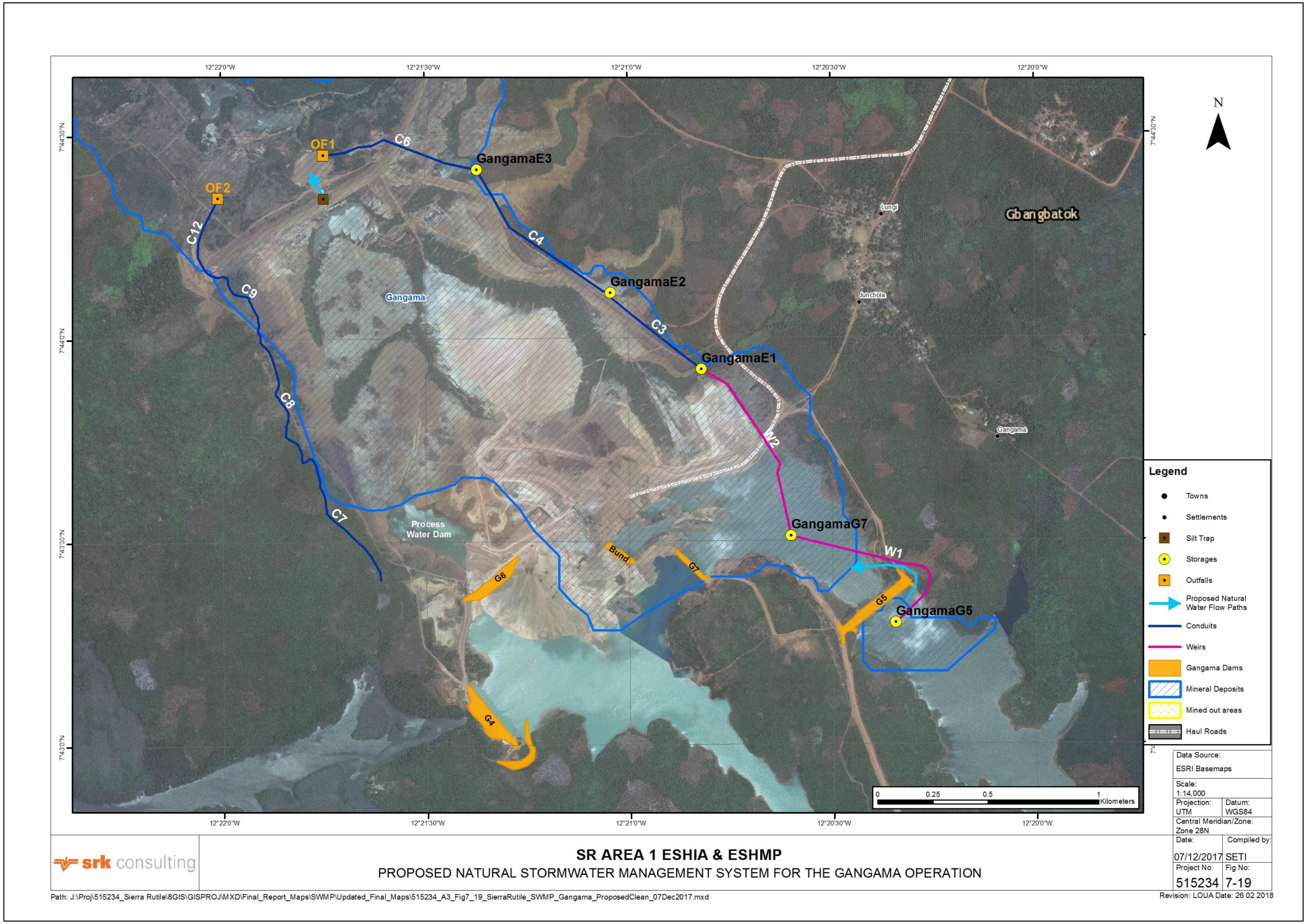


Figure 7-19: Proposed natural stormwater management system at the Gangama operation

7.3.6 Gbeni Operation

Presently, there is a natural water diversion drain (Gbeni West Trench) that extends up slope for most of the western edge of the Gbeni deposit (see Figure 7-20). This drain has been sized and extended further upstream in the proposed natural water management system. A silt trap installation is proposed upstream of the discharge point.

The Gbeni East Trench has been sized and formalised. The natural water management system for the eastern portion of the Gbeni area includes spillways from GB3 Dam to encourage a downstream flow into the first earthen holding dam. In addition, another natural water diversion drain will direct the flow of water into the same holding dam from where it will join another channel into a second holding dam. The second holding dam divert the flow of water into another clean water diversion from where it will discharge into the environment. Prior to the discharge, a silt trap installation is proposed to limit the amount of sediment released into the Lanti Stream.

There are also smaller channels draining the middle section of the deposit. This natural water runoff will flow into the proposed natural water system.

7.3.7 Nitti Port

The Nitti Port proposed natural water management system consists of a natural stormwater runoff diversion bump at the gate to the complex that will ensure that any natural stormwater runoff is directed towards the mangroves rather than into the Nitti Port. This can be seen in Figure 7-21.

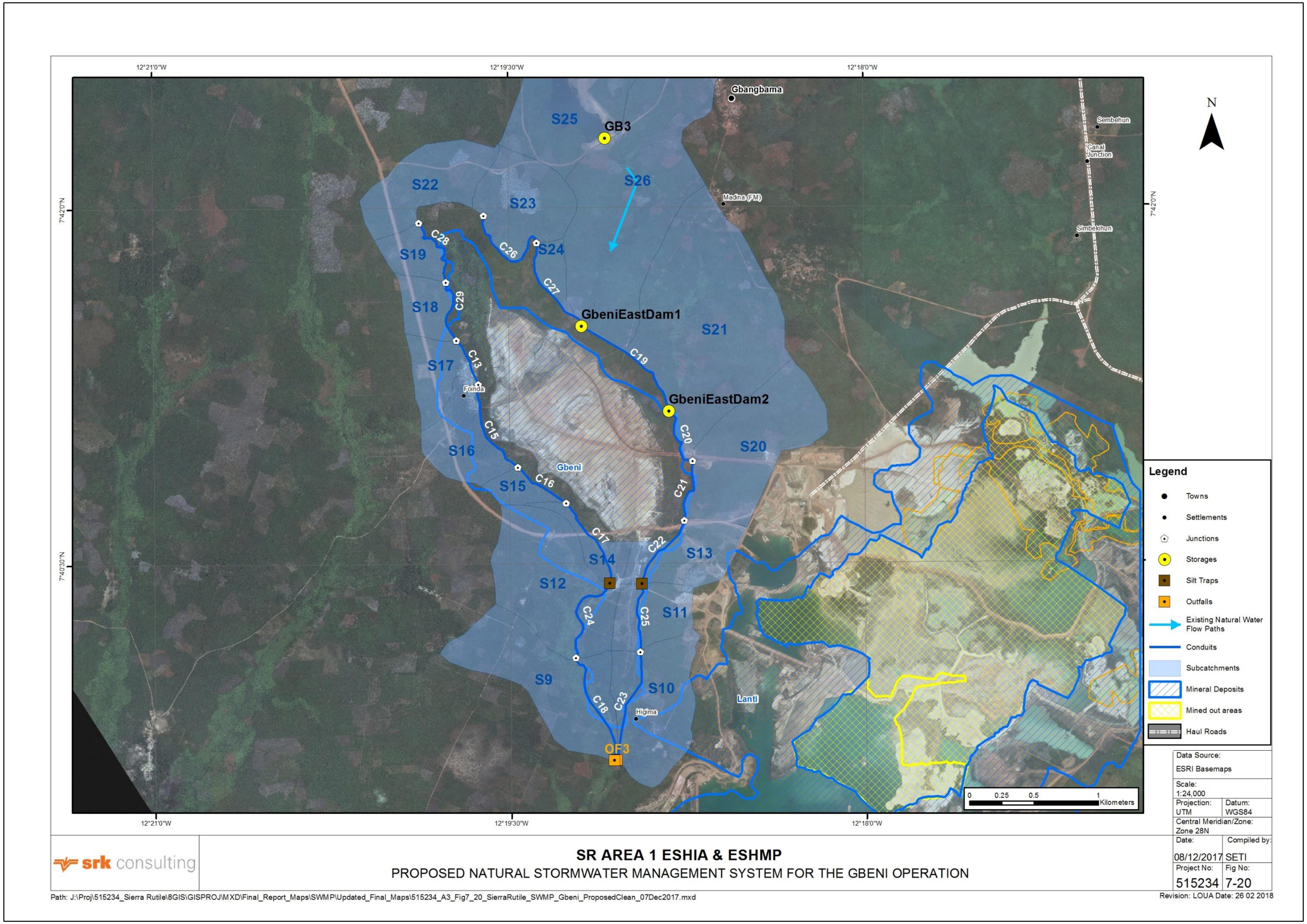


Figure 7-20: Proposed natural stormwater management system at the Gbeni operation

Figure 7-21: Proposed natural stormwater management system at the Nitti Port operation

7.4 Proposed mine impacted stormwater management

The proposed mine impacted stormwater system at SRL is described in the subsections that follow.

7.4.1 Mineral Separation Plant

There are no changes to the mine impacted stormwater management procedures at the MSP. However, it was intimated that a berm will be constructed to prevent the flow of process water into the Mogbwemo Domestic Reservoir. This berm will redirect the process water (and tailings drainage) back into the Mogbwemo Dredge Pond (personal communication, 21 August 2017). The location of this berm is shown in Figure 7-22.

7.4.2 Dry Mining Plant 1 (DM 1 - Lanti Operation)

There are no changes to the mine impacted stormwater management procedures at the Lanti operation. Oil spill kits should be used during operations.

7.4.3 Dry Mining Plant 2 (DM 2 - Gangama Operation)

A silt trap is proposed to limit the amount of sediment released into the environment. Oil spill kits should be used during operations. The proposed mine impacted water system for the Gangama operation is shown in Figure 7-23.

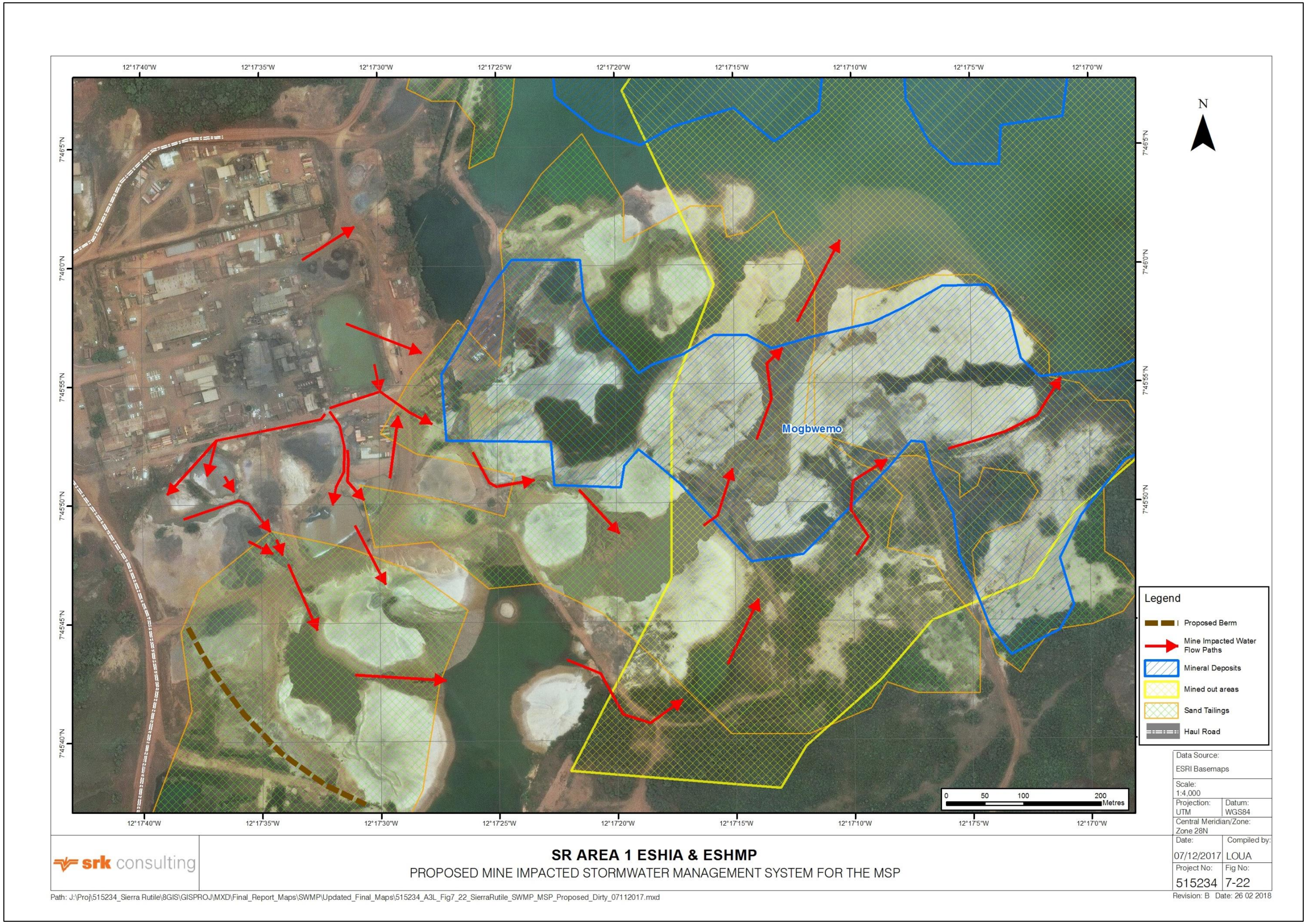


Figure 7-22: Proposed mine impacted stormwater management system at the MSP

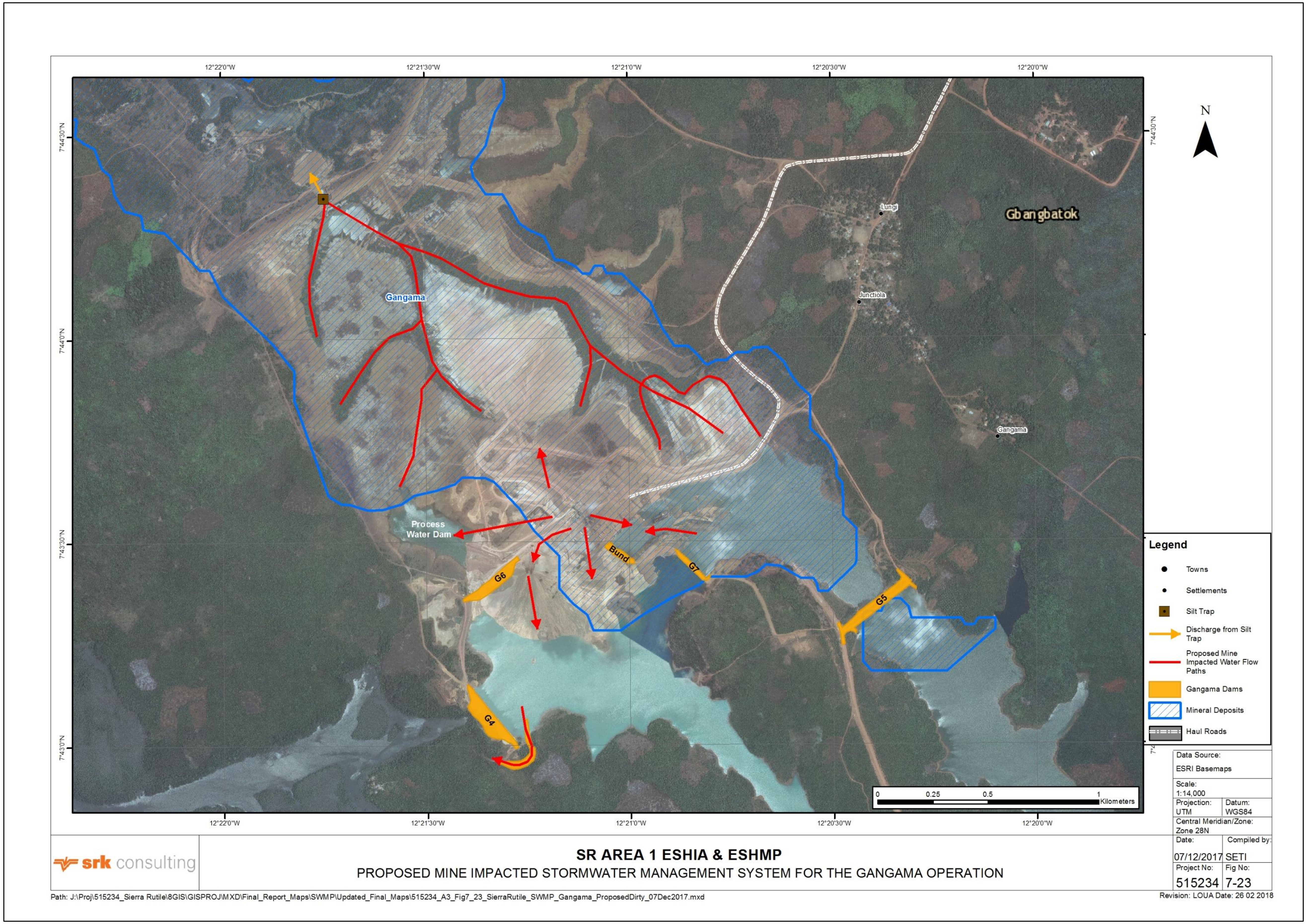


Figure 7-23: Proposed Mine impacted stormwater management system at the Gangama operation

7.4.4 Gbeni Operation

TherThe changes proposed to the mine impacted stormwater management system for the Gbeni site include directing the stormwater flowing into the pit area towards the Gbeni West Trench and East Trench before flowing through a silt trap and finally discharging into the environment. This can be seen in Figure 7-24.

7.4.5 Nitti Port

The proposed changes to the mine impacted water management system at Nitti Port include upgrading the northern silt trap, sizing it correctly and formalising it. A southern boundary channel must be constructed to flow into the proposed southern silt trap from the west (from the estuary). A natural water diversion bump should be constructed at the entrance to the Nitti Port area to prevent additional natural stormwater runoff from entering the site. The proposed mine impacted water management system is illustrated in Figure 7-25.

7.5 Stormwater collection drainage

7.5.1 Flood peak calculations

The sub-catchment areas for the stormwater management plan were identified (these are depicted in Figure 7-19 and Figure 7-20). The modelling input parameters used to calculate the stormwater runoff peaks are presented Table 7-1.

Catchment characteristics

Table 7-1 presents the catchment parameters used in the modelling**.** Manning's 'n' coefficient for the impervious areas and pervious areas was 0.012 and 0.8 respectively. The depression storage on impervious and pervious areas was set at 2 mm. The Green-Ampt infiltration parameters were for a 'sandy clay loam' soil type.

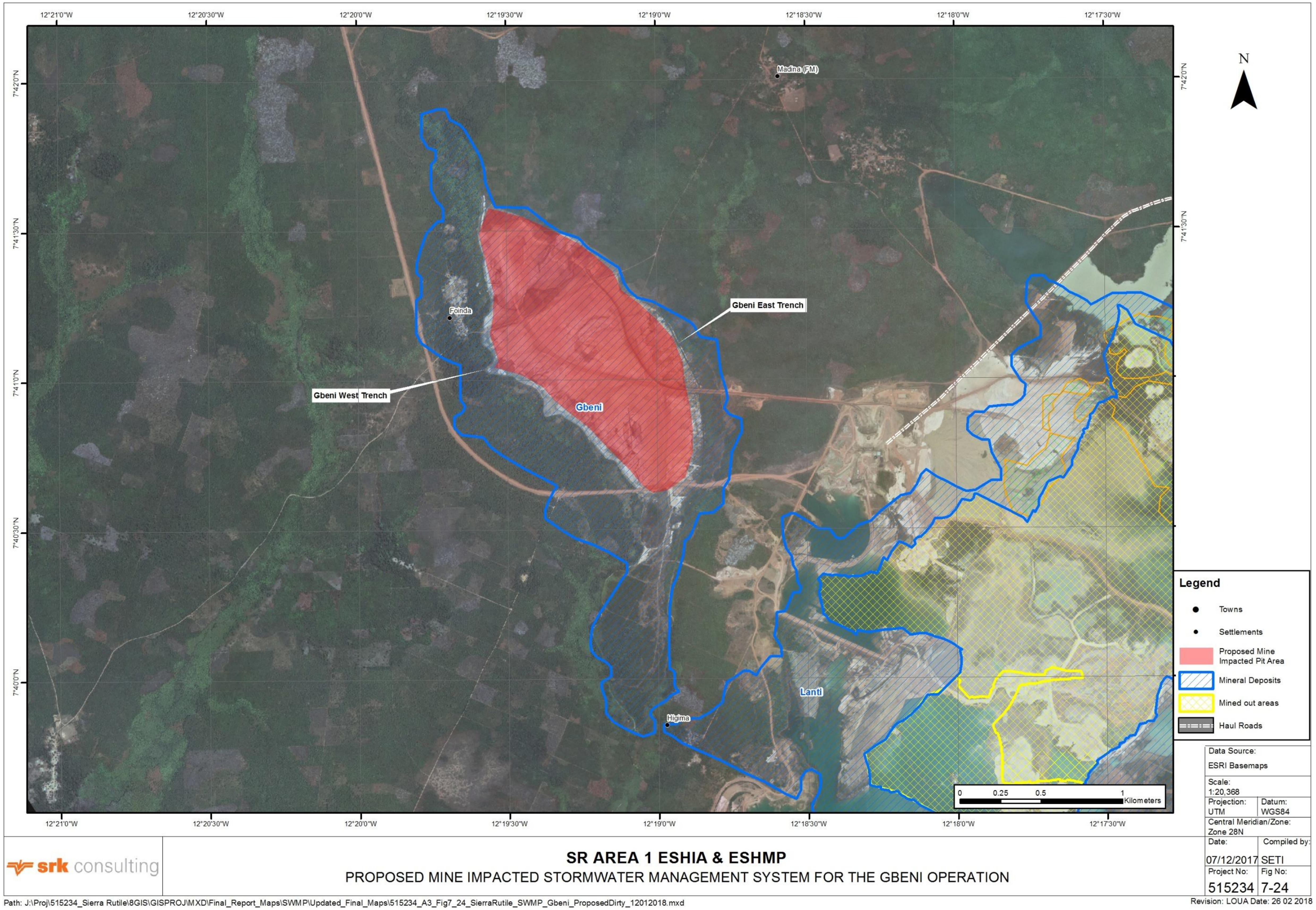


Figure 7-24: Proposed mine impacted stormwater management system at the Gbeni operation

Figure 7-25: Proposed mine impacted stormwater management system at the Nitti Port

Table 7-1: Sub-catchment parameters used in modelling the SRL mine site-wide stormwater management plan

Name	Area (ha)	Width (m)	Flow length (m)	Slope (%)	Green-Ampt Infiltration - suction head (mm)	Green-Ampt Infiltration - conductivity (mm/h)
Gangama Operation						
S1	69.2	600	1153.3	3.56	218.5	1.5
S2	215.2	1070	2011.4	3.48	218.5	1.5
S3	60.2	600	1003.4	4.10	218.5	1.5
S4	144.5	1500	963.2	3.36	218.5	1.5
S5	29.1	420	693.7	5.22	218.5	1.5
S6	28.4	470	604.0	6.66	218.5	1.5
S7	22.7	300	757.3	5.68	218.5	1.5
S8	348.5	1500	2323.6	4.49	218.5	1.5
Gbeni Operation						
S9	73.8	940	784.8	1.78	218.5	1.5
S10	61.3	980	625.2	3.20	218.5	1.5
S11	27.8	450	617.7	4.05	218.5	1.5
S12	79.4	1010	785.9	1.78	218.5	1.5
S13	34.1	510	669.2	2.24	218.5	1.5
S14	13.7	150	912.7	1.11	218.5	1.5
S15	9.7	290	333.2	2.4	218.5	1.5
S16	32.6	660	494.5	1.82	218.5	1.5
S17	22.2	475	467.8	3.83	218.5	1.5
S18	17.3	475	364.3	5.22	218.5	1.5
S19	15.4	400	385.0	5.97	218.5	1.5
S20	74.7	580	1288.3	4.66	218.5	1.5
S21	150.6	1260	1195.2	5.02	218.5	1.5
S22	45.2	500	903.5	0.50	218.5	1.5
S23	46.2	725	637.7	7.03	218.5	1.5
S24	10.0	270	370.5	5.41	218.5	1.5
S25	612.0	1700	3600.2	8.22	218.5	1.5
S26	163.5	740	2208.9	4.75	218.5	1.5

Calculated flood peaks

The PCSWMM programme was used to generate the peak runoff and stormwater volumes for the sub-catchments shown in Figure 7-19 and Figure 7-20. The flood peaks calculated for the 1:50 year Return Period rainfall are shown in Table 7-2.

Table 7-2: Computed 1:50 year flood peaks (m^3/s) and runoff volumes

Catchment	1:50 year return period peak (m^3/s)	Runoff volume (m^3)
Gangama Operation		
S1	12.2	162 450
S2	23.6	438 100
S3	12.6	146 600
S4	28.8	348 500
S5	8.9	75 340
S6	10.5	74 950
S7	6.7	58 490
S8	37.7	705 710
Gbeni Operation		
S9	13.4	174 450
S10	16.8	156 200
S11	8.4	71 800
S12	14.4	187 660
S13	7.7	84 390
S14	1.8	29 690
S15	3.8	25 660
S16	8.6	82 760
S17	8.1	58 590
S18	8.4	46 680
S19	7.5	41 570
S20	13.4	176 220
S21	29.6	362 340
S22	4.3	86 860
S23	16.7	121 830
S24	4.8	26 990
S25	75.4	1 297 340
S26	18.9	3 391 50

7.6 Silt traps

Silt traps will be required upstream of the discharge point at the internal mine impacted water channels at the Gangama operations and both natural water diversion drains at Gbeni operations. In order to adequately size the silt traps, a particle density analysis on the stormwater at various sites would be required. This exercise falls beyond the scope of this study but should be considered for future analysis.

The locations of the proposed silt traps are shown in Figure 7-19 and Figure 7-20.

Dual-compartment silt traps are recommended to allow for maintenance / cleaning during operation. In addition, the silt traps should be fitted with a high-flow bypass channel to prevent washout during flow rates that exceed the desired parameters.

7.7 Conclusions and recommendations for the SWMP

Conclusions and recommendation for the SWMP include:

- The stormwater requirements as described above are only one potential solution to separate natural and mine impacted water. During the detailed design phase, there may be some variation to the option presented in this study;
- The construction of silt traps at the Gangama and Gbeni operations and a stormwater diversion bump at the Lanti DM 1 Plant and the Nitti Port;
- To prevent erosion at the outfall of the system, energy dissipation and erosion-control structures should be constructed; and
- Authorisations must be obtained prior to the commencement of any such activity.

8 Water Balance

The daily water balance for the MSP, Gangama operations (DM2) and Lanti operations (DM1) was designed using the Goldsim Monte Carlo simulation software. GoldSim is an advanced programme with a flexible simulation platform that is able to visualize and dynamically simulate almost every kind of environmental system and associated risks.

8.1 Water balance results

A schematic flow diagram of the process water reticulation system for SRL was included in the data received from the mine and was used for the design of the water balance. Water requirements for DM1 were provided for June 2017 and were used as an average in the water balance calculation. The Plant water requirements were provided for the DM2 and MSP and were used to determine the input water requirements.

Some of the water use included in the water balance is (presently) estimated by calculation because the actual / meter data was not available at all the points. These estimations are based on assumptions listed in Table 8-1.

These assumptions can be modified at any stage to generate an adjusted reading.

The layout plan indicating the various areas used in the water balance are presented in Figure 8-1 and Figure 8-2.

Table 8-1: Assumptions and variables

Aspect	Value
DM1 Constants	
C3 area	452 963 m^2
CP6 area	1 215 055 m^2
CP9 area	686 820 m^2
CP11A area	316 653 m^2
CP11B area	86 911 m^2
CP12 area	291 752 m^2
L4 area	916 604 m^2
CP8 A + CP8B	373 874 m^2
CP1 area	461 497 m^2
C3 volume	2 717 778 m^3
L4 volume	8 490 397 m^3
CP8A volume	1 121 624 m^3
CP8B volume	1 121 624 m^3
Plant decant	2 736 m^3/hr
Moisture in Feed	1 m^3 per RHF ton
Plant water requirements	13 679 m^3/d
Water in Ore	1 573 m^3/d
Runoff	50% of Rainfall
	DM2 Constants
GB3 area	395 891 m^2
GB5 area	694 111 m^2

Aspect	Value
GB7 area	541 218 m^2
Gangama Pump Station area	3 012 m^2
G4 area	795 373 m^2
MSP area	7 111 m^2
Plant water requirements	2 100 m^3/hr
Moisture in Feed	10%
	MSP Constants
Bamba Pond area	6 981 648 m^2
D3 Pond area	1 000 m^2
Lake Grey area	5 000 m^2
Tailings area	100 000 m^2
Plant water requirements	2 200 m^3/hr

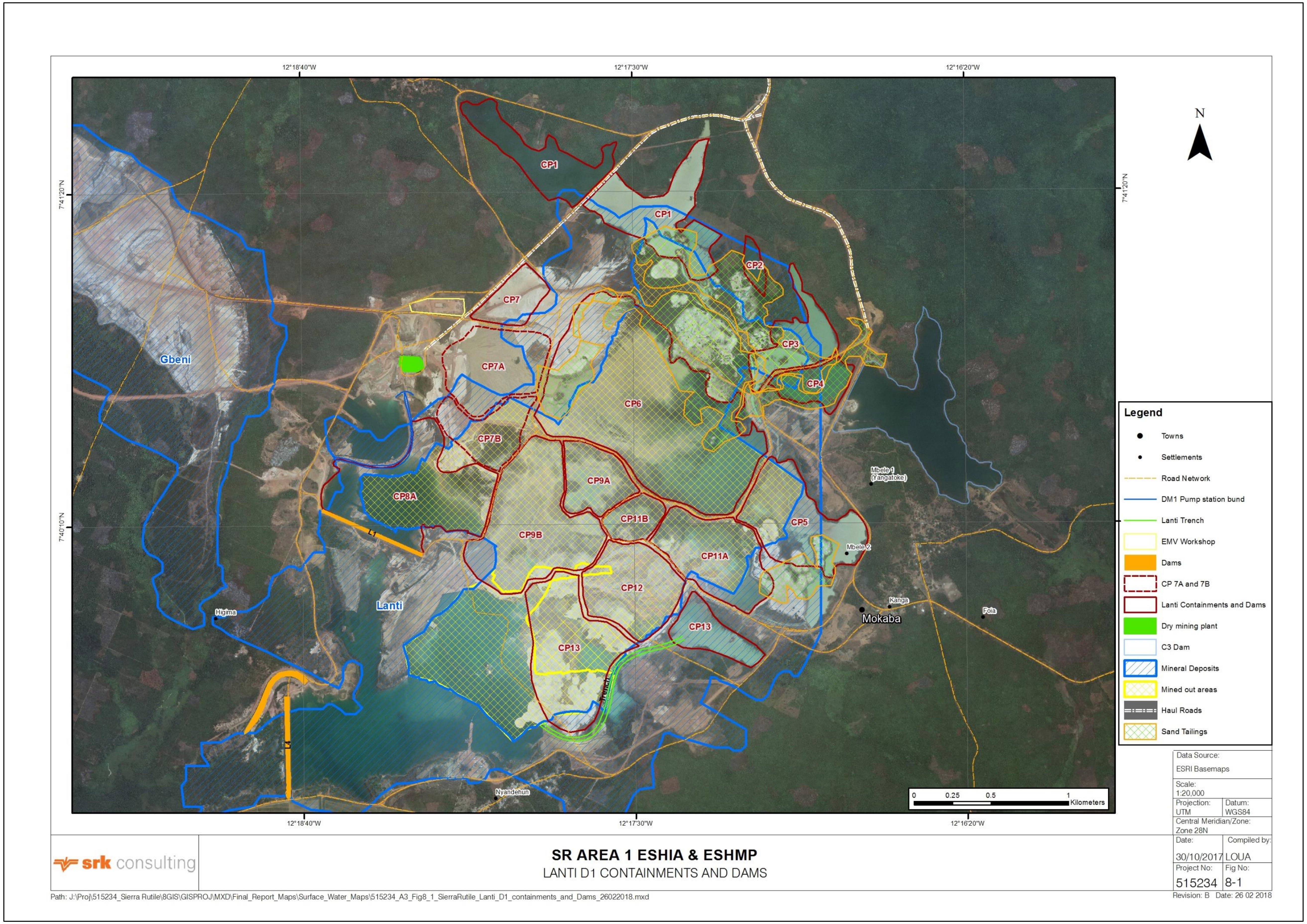


Figure 8-1: Lanti DM1 containments and dams

Figure 8-2: Gangama DM2 tailings and water storage facilities

A schematic diagram showing the flow of water to and from the three sites with the approximate quantities in m^3/d on average (for the year and / monthly average) is shown in Figure 8-3 to Figure 8-5. The relevant inputs (including rainfall and water pumped from the stream) are shown on the left-hand-side. The diagram illustrates the circulating flow of water through the system. The values on the right represent output (consumption, evaporation and other losses).

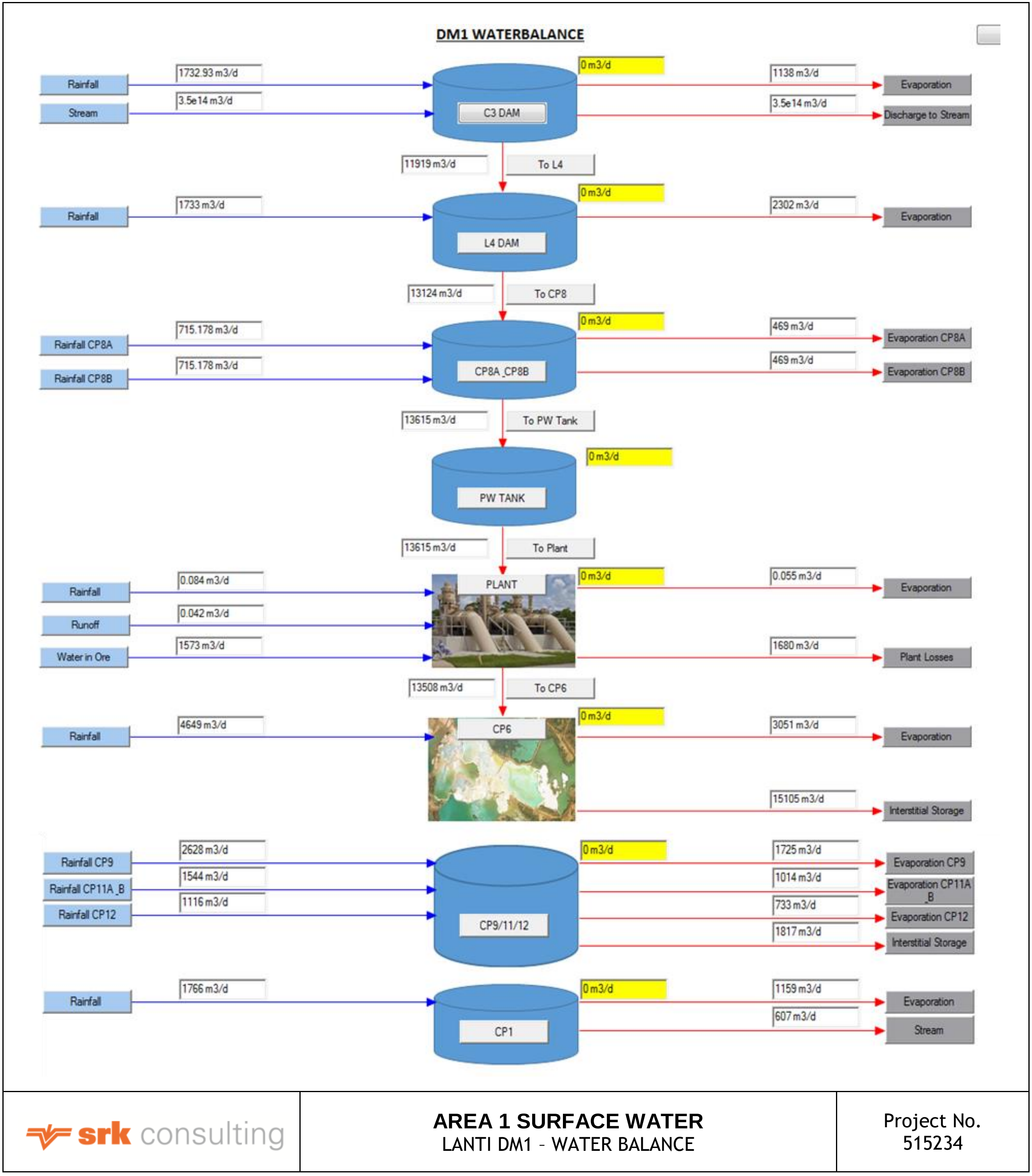


Figure 8-3: Lanti DM1 – water balance

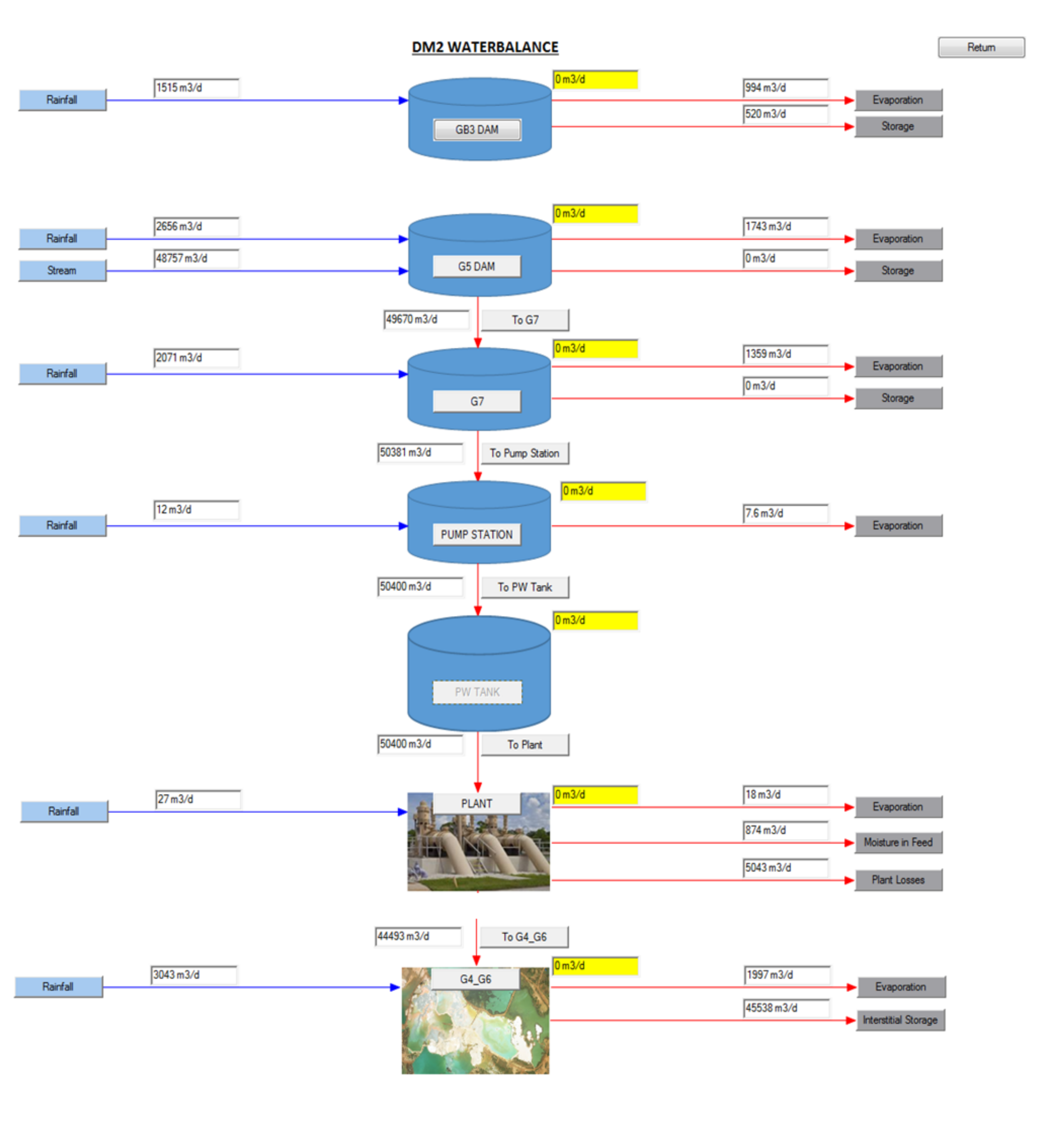


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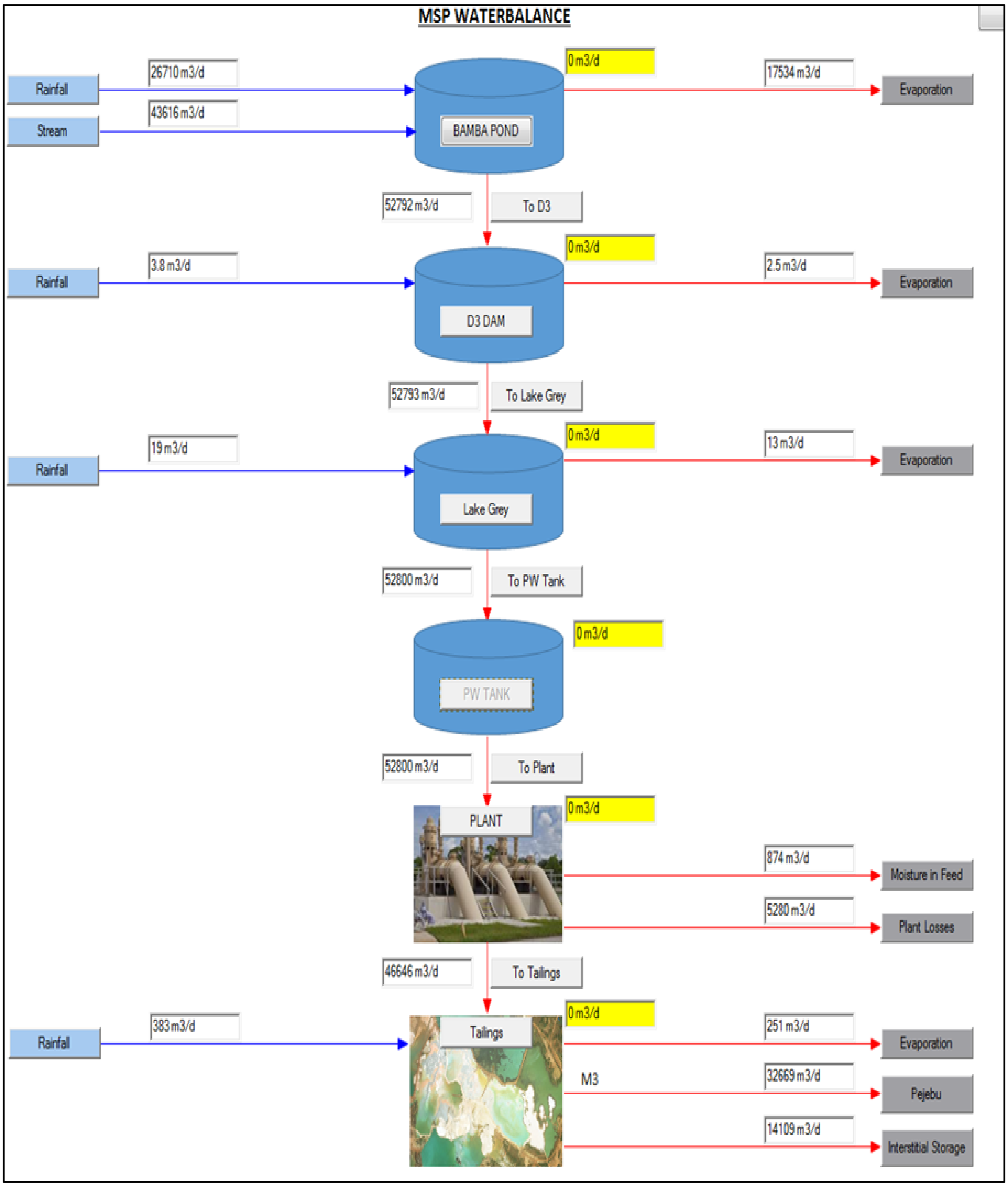
Figure 8-4: Gangama DM2 – water balance



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GANGAMA DM2 - WATER BALANCE

Project No.
515234

Figure 8-5: MSP – water balance

The SRL mine requires a substantial reading of data. At this stage, the lack of sufficient meter data limits the possibility of an accurate reading. With further detail, the water balance can be updated with a greater degree of accuracy.

The platform for data entry is basic. With further detail, the model can be updated directly from an accessible programme like Excel.

8.2 Recommendations for the water balance

The monthly water requirement has been generated using the current rainfall data and available Plant water requirements for each site.

SRK recommends the following:

- Update the water balance with daily MSP requirements;
- Update the surface area and volumes of the ponds at the MSP to eliminate the assumption; and
- As the meter data (numbers, locations etc.) becomes available, it should be used to update the water balance. An update will assist with the accurate identification of the water demands at each facility and ensure efficient water management practice.

9 Water Quality

The water quality data presented in this section was captured during three sampling sessions conducted by SRL in July, August and October 2017. The water samples were analysed by Exova Jones Environmental Laboratory. The analytical suite included physical and chemical determinants.

9.1 Monitoring network

The surface water monitoring network is summarised in Table 9-1 and shown in Figure 9-1. These sites were chosen to monitor the effects of mining and the processing plants on the quality of surface water within the Area 1.

Table 9-1: Surface water monitoring points

Surface Water Monitoring Points			
Name	**X**	**Y**	**Area of Interest**
SW 1	803597.995	862223.807	Mogbwemo Dredge Pond effluent. This point was selected as it is the furthest point from the MSP in Mogbwemo Dredge Pond to identify potential buffering in the pond.
SW 2	800211.413	856826.829	Motinga Pond. This point was selected as it is the point near the pineapple plantation.
SW 3	805741.584	856072.253	Pejebu Dredge Pond effluent. This point was selected as it is one of the points that discharges from the mine area into the Tikote Stream.
SW 4	796586.798	847620.967	Lanti North Dredge Pond effluent. This point was selected as it is one of the points that discharges from the mine area into the Lanti Stream.
SW 5	794955.705	850507.935	This point is situated to the west of the Gbeni pit in the west natural water diversion trench. This point was chosen as it describes the water quality of the upstream flow.
SW 6	793504.674	854471.053	G5 Dam upstream of the Gangama operations. This is the background point selected for the study.
SW 8	790928.938	856494.679	Gangama north downstream of the dry mining below the breached G1 wall. This point was selected as it is one of the points that discharges from the mine area into the unnamed stream.
SW 9	786873.274	860151.835	This point is located alongside the jetty at Nitti Port.
SW 12	790566.476	860895.645	This point is located downstream of the discharge point from the Bamba/Belebu Dredge Pond near the Gbangbaia village.
SW 14	795132.000	859119.000	This point is located downstream of the discharge point from the Bamba/Belebu Dredge Pond. This stream is not impacted by the MSP.
SW 15	797340.000	859075.000	Mogbwemo Domestic Pond. This point can only be potentially impacted from the historical mining that took place when the Motinga and Titan Ponds were mined 40 years ago.
SW 17	799948.000	859428.000	Mogbwemo Dredge Pond near MSP upstream of Kpetema bund.
SW 18	802735.412	860583.365	Mogbwemo Domestic Pond discharge to Pejebu Pond into the M3 channel.
SW 19	798843.353	858787.793	Discharge from MSP tailings into channel

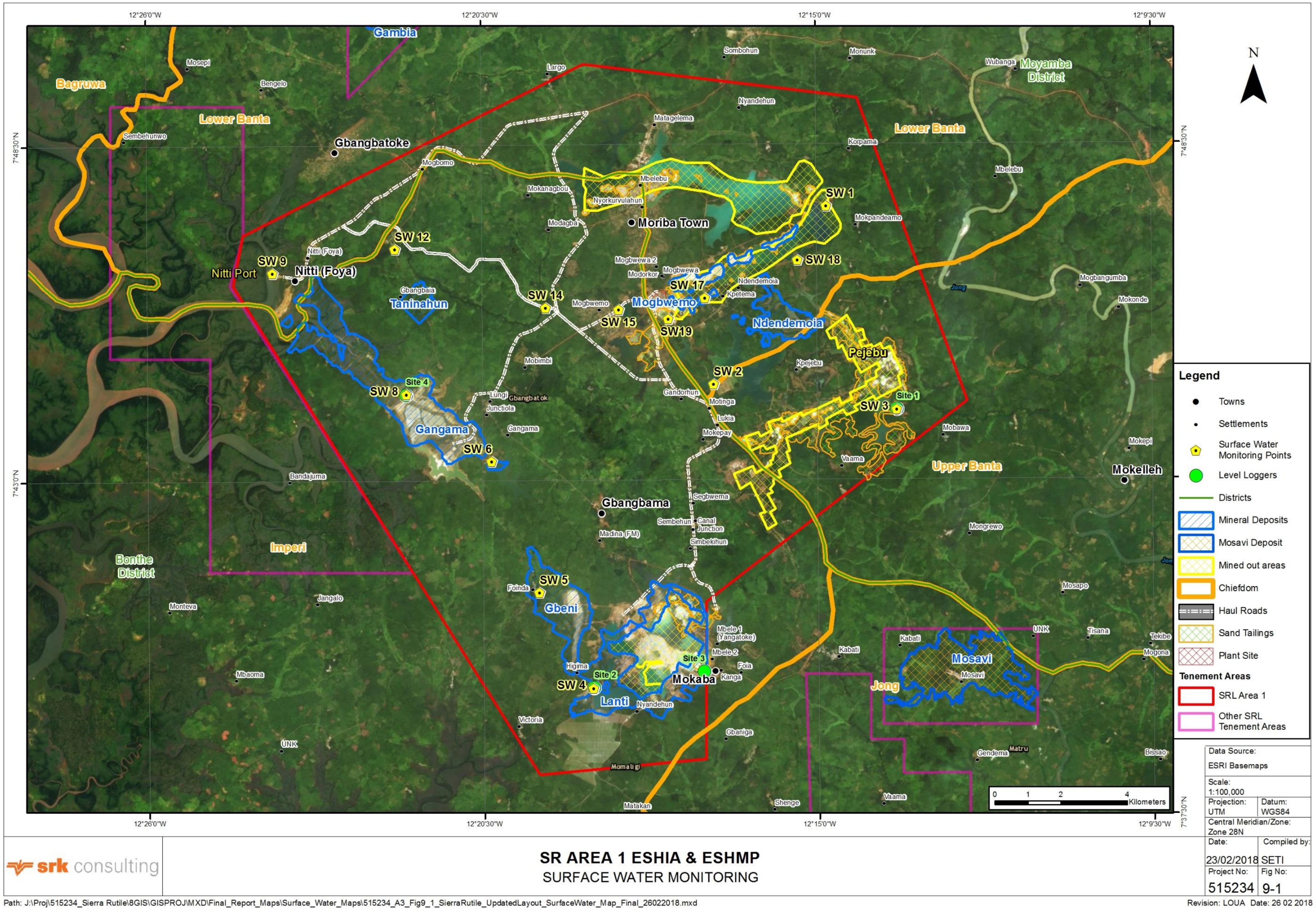


Figure 9-1: Surface water monitoring network

9.2 Water quality summary

Table 9-2 presents a summary of the results of the surface water quality monitoring undertaken in July, August and October 2017 relative to the guideline limits required by the legislation as well as the guideline limits for domestic water use. The limits of detection (LOD) are shown and the water quality parameters that exceed guideline limits are highlighted in Table 9-2 and described further in Table 9-3.

The pH and the EC concentrations for the monitoring points (August dataset) are shown in Figure 9-2 and Figure 9-3 respectively.

The background surface water quality for the area is taken as the sample collected at the monitoring point SW 6. This point is not up gradient of the mine activities, but is sufficiently distant from the mining activities and therefore possibly represents the least affected surface water monitoring point within the Area 1. The water quality is compared to the average background water quality value, average for July, August and September (orange text) and to the guidelines as detailed in Table 9-2.

Table 9-2: Surface water quality analysis

Parameter: Analyses in mg/ℓ (Unless specified otherwise)	Units	SANS 241:2015 (Standard Limits for Potable Water)	Applicable		LOD	SW 6 - Baseline				SW 1			SW 2			SW 3			SW 4			SW 5			SW 8		
			Sierra Leone	World Bank Guidelines																							
			Environmental and Social Regulations for Mining 2013	Mining (IFC EHS) 2007		Jul	Aug	Oct	Average	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct
pH – Value at 25°C *	S.U.	5 - 9.7	6 - 9	6 - 9	0.010	6.3	6.0		6.2	3.7	3.5	3.7	6.3	5.9		4.5	4.5		4.2	4.3		6.9	6.6		6.3	5.8	
Electrical Conductivity in mS/m at 25°C	mS/m	170			0.500	0.95	1.01	0.97	0.98	13.69	12.52	11.13	0.86	1.15	0.81	3.14	2.40	2.32	4.58	3.18	3.94	2.45	1.82	1.48	1.40	1.51	1.27
Total Dissolved Solids at 180°C *	mg/l	1200			35.000	35.00	35.00		35.00	35.00	57.00	39.00	35.00	35.00		35.00	35.00		35.00	35.00		35.00	35.00		35.00	35.00	
Colour in PtCo Units *	mg/l Pt-Co	15																									
Turbidity in N.T.U	NTU	1			0.100	1.50	1.50		1.50	1.30	0.70	0.30	1.70	2.50		1.00	1.00		0.90	1.50		6.70	7.80		7.10	13.60	
Chloride as Cl	mg/l	300			0.300	1.80	1.50	1.80	1.70	2.00	1.60	1.60	6.80	1.60	1.70	1.80	1.50	1.80	2.10	1.60	1.80	2.20	1.70	1.90	1.90	1.50	1.90
Sulphate as SO4	mg/l	500			0.500	2.40	2.20		2.30	24.00	24.50	18.70	8.90	2.30		6.70	5.70		9.00	6.90		2.50	2.40		2.80	3.20	
Fluoride as F	mg/l	1.5			0.300	<0.300	<0.300	<0.300	0.30	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Nitrate as N	mg/l	11			0.050	0.23	0.38		0.31	0.27	<0.050	0.25	1.11	0.41		0.23	0.38		0.23	0.38		0.25	0.41		0.38	0.70	
Calcium as Ca	---	---			0.200		2.00	2.00	2.00		2.00	2.00		2.00	2.00		2.00	2.00		2.00	2.00		2.00	2.00		2.00	2.00
Magnesium as Mg	---	---			0.100		1.00	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00
Aluminium as Al	mg/l	0.3			0.020		0.09	0.04	0.06		0.90	0.72		0.14	0.06		0.12	0.12		0.13	0.17		0.65	0.34		0.34	0.42
Antimony as Sb*	mg/l	0.02			0.002		<0.002	<0.002	0.002		<0.002	0.01		<0.002	<0.002		<0.002	<0.002		<0.002	<0.002		<0.002	<0.002		<0.002	0.00
Arsenic as As*	mg/l	0.01	0.1	0.1	0.003		0.00	0.00	0.003		0.00	0.003		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00
Cadmium as Cd	mg/l	0.003	0.05	0.05	0.001		<0.001	<0.001	0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001
Total Chromium as Cr	mg/l	0.05		0.1	0.002		<0.002	<0.002	0.002		<0.002	<0.002		<0.002	<0.002		<0.002	<0.002		<0.002	<0.002		0.00	<0.002		<0.002	0.00
Copper as Cu	mg/l	2	0.6	0.3	0.007		<0.007	<0.007	0.007		<0.007	<0.007		<0.007	<0.007		<0.007	<0.007		<0.007	<0.007		<0.007	<0.007		<0.007	<0.007
Iron as Fe	mg/l	2	2	2	0.020		0.43	0.67	0.55		0.12	0.16		0.40	0.29		0.21	0.12		0.06	0.02		1.12	0.44		0.49	1.24
Lead as Pb	mg/l	0.01	0.2	0.2	0.005		0.01	0.01	0.005		0.005	0.01		0.01	0.01		0.01	0.01		0.01	0.01		0.01	0.01		0.01	0.01
Manganese as Mn	mg/l	0.4			0.002		0.01	0.02	0.015		0.13	0.12		0.01	0.01		0.03	0.04		0.03	0.04		0.05	0.05		0.05	0.05
Nickel as Ni	mg/l	0.07		0.5	0.002		0.00	0.00	0.002		0.01	0.01		0.00	0.00		0.00	0.00		0.01	0.01		0.00	0.00		0.00	0.00
Selenium as Se*	mg/l	0.04			0.003		0.00	0.00	0.003		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.01		0.00	0.00		0.00	0.00
Zinc as Zn	mg/l	5	1.5	0.5	0.003		0.00	0.00	0.003		0.01	0.01		0.01	0.00		0.00	0.00		0.01	0.00		0.00	0.00		0.00	0.00
Total Suspended Solids (TSS)	mg/l		50	50	10.000	<10.000	<10.000		10.000	<10.000	<10.000	<10.000	<10.000	<10.000		<10.000	<10.000		<10.000	<10.000		<10.000	14.000		<10.000	12.000	
Mercury (total)	mg/l		0.002	0.002	0.001		<0.001	<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001		<0.001	<0.001
Chemical Oxygen Demand (COD)	mg/l			150	9	19	<9	<9	12	<9	<9	14	14	<9	<9	<9	<9	<9	<9	<9	<9	16	<9	<9	16	<9	<9

Parameter: Analyses in mg/ℓ (Unless specified otherwise)	Units	SANS 241:2015 (Standard Limits for Potable Water)	Applicable: Sierra Leone – Environmental and Social Regulations for Mining 2013	Applicable: World Bank Guidelines – Mining (IFC EHS) 2007	LOD	SW 6 - Baseline				SW 9			SW 12			SW 14			SW 15			SW 17			SW 18		SW 19	
						Jul	Aug	Oct	Average	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Jul	Aug	Oct	Aug	Oct	Aug	Oct
pH – Value at 25°C *	S.U.	5 - 9.7	6 - 9	6 - 9	0.010	6.3	6.0		6.2	7.1	6.7		6.5	6.4		6.0	5.8		4.7	4.2		3.4	3.2		3.5		2.9	
Electrical Conductivity in mS/m at 25°C	mS/m	170			0.500	0.95	1.01	0.97	0.98	128.10	43.00	109.20	1.05	20.73	1.94	1.95	1.60	1.63	2.78	4.02	3.43	21.80	23.50	22.10	12.46	16.29	51.40	66.00
Total Dissolved Solids at 180°C *	mg/l	1200			35.000	35.00	35.00		35.00	692.00	245.00		35.00	102.00		35.00	35.00		48.00	66.00		62.00	55.00		35.00		117.00	
Colour in PtCo Units *	mg/l Pt-Co	15																										
Turbidity in N.T.U	NTU	1			0.100	1.50	1.50		1.50	46.40	36.10		0.40	2.90		1.10	3.00		1.90	1.40		0.20	3.10		10.60		4.20	
Chloride as Cl	mg/l	300			0.300	1.80	1.50	1.80	1.70	365.20	110.50	295.40	2.10	49.70	2.50	2.10	1.60	1.80	2.20	1.50	1.80	2.00	1.60	2.20	1.60	1.70	1.50	1.60
Sulphate as SO4	mg/l	500			0.500	2.40	2.20		2.30	43.70	15.10		1.80	10.50		5.30	3.90		6.50	8.60		36.20	41.10		22.90		88.80	
Fluoride as F	mg/l	1.5			0.300	< 0.300	< 0.300	< 0.300	0.30	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300
Nitrate as N	mg/l	11			0.050	0.23	0.38		0.31	0.23	< 0.050		0.23	0.45		0.25	0.38		0.23	0.38		0.23	0.38		< 0.050		0.38	
Calcium as Ca	---	---			0.200		2.00	2.00	2.00		2.90	6.80		2.00	2.00		2.00	2.00		2.00	2.00		2.00	2.00	2.00	2.00	2.00	2.00
Magnesium as Mg	---	---			0.100		1.00	1.00	1.00		8.20	23.90		3.80	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00
Aluminium as Al	mg/l	0.3			0.020		0.09	0.04	0.06		2.64	0.66		0.15	0.21		0.13	0.14		0.31	0.24		1.04	1.21	0.62	0.91	2.14	3.63
Antimony as Sb*	mg/l	0.02			0.002		< 0.002	< 0.002	0.002		< 0.002	< 0.002		< 0.002	< 0.002		< 0.002	< 0.002		< 0.002	< 0.002		< 0.002	0.00	< 0.002	< 0.002	< 0.002	0.00
Arsenic as As*	mg/l	0.01	0.1	0.1	0.003		0.00	0.00	0.003		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
Cadmium as Cd	mg/l	0.003	0.05	0.05	0.001		< 0.001	< 0.001	0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Total Chromium as Cr	mg/l	0.05		0.1	0.002		< 0.002	< 0.002	0.002		0.00	< 0.002		< 0.002	< 0.002		< 0.002	< 0.002		< 0.002	< 0.002		< 0.002	0.00	< 0.002	< 0.002	< 0.002	0.00
Copper as Cu	mg/l	2	0.6	0.3	0.007		< 0.007	< 0.007	0.007		< 0.007	< 0.007		< 0.007	< 0.007		< 0.007	< 0.007		< 0.007	< 0.007		< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Iron as Fe	mg/l	2	2	2	0.020		0.43	0.67	0.55		1.79	0.50		0.40	0.70		0.36	0.36		0.13	0.06		0.32	0.51	0.17	0.31	2.84	5.23
Lead as Pb	mg/l	0.01	0.2	0.2	0.005		0.01	0.01	0.005		0.01	0.01		0.01	0.01		0.01	0.01		0.01	0.01		0.01	0.01	0.01	0.01	0.01	0.01
Manganese as Mn	mg/l	0.4			0.002		0.01	0.02	0.015		0.02	0.01		0.02	0.01		0.05	0.07		0.08	0.07		0.10	0.12	0.09	0.12	0.23	0.44
Nickel as Ni	mg/l	0.07		0.5	0.002		0.00	0.00	0.002		0.00	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.01	0.02	0.01	0.01	0.01	0.02
Selenium as Se*	mg/l	0.04			0.003		0.00	0.00	0.003		0.00	0.01		0.00	0.01		0.00	0.00		0.00	0.01		0.00	0.00	0.00	0.00	0.00	0.00
Zinc as Zn	mg/l	5	1.5	0.5	0.003		0.00	0.00	0.003		0.01	0.00		0.00	0.00		0.01	0.00		0.01	0.00		0.02	0.02	0.01	0.02	0.02	0.03
Total Suspended Solids (TSS)	mg/l		50	50	10.000	< 10.000	< 10.000		10.000	60.000	41.000		< 10.000	< 10.000		22.000	< 10.000		< 10.000	< 10.000		< 10.000	< 10.000		20.000		27.000	
Mercury (total)	mg/l		0.002	0.002	0.001		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Chemical Oxygen Demand (COD)	mg/l			150	9	19	< 9	< 9	12	23	< 9	< 9	13	< 9	< 9	10	< 9	< 9	12	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9

*unfiltered

LEGEND

(blue)	Drinking Water/WHO 2017#SANS 2015
(orange)	Environmental and Social Regulations for Mining 2013
(yellow)	Mining (IFC EHS) 2007
123	Exceeding the Background WQ (SW 6 Average)

Table 9-3: Water quality comments

Name	Location	Comment
SW 1	Mogbwemo Dredge Pond effluent	pH exceeded the Sierra Leone legislative limits. There is no discharge directly from this point. The quality is elevated above the background concentrations in terms of EC, sulfate, aluminum, manganese, nickel, zinc and COD. Aluminium exceeded the SANS drinking water guidelines.
SW 2	Motinga Pond	pH exceeded the Sierra Leone legislative limits in August, but was not measured in October. The quality was elevated above the background concentrations in terms of nitrate, sulfate, zinc and COD in July and August, but concentrations were comparable to the background quality in October. The quality was within the SANS drinking water guidelines.
SW 3	Pejebu Dredge Pond effluent	pH exceeded the Sierra Leone legislative limits. This was not measured in October. The quality was elevated above background in terms of sulfate, nitrate and manganese in July and/or October, but only manganese remained elevated in October. The quality was within the SANS drinking water guidelines.
SW 4	Lanti North Dredge Pond effluent	pH exceeded the Sierra Leone legislative limits. This was not measured in October. The quality was elevated above background in terms of sulfate, nitrate, manganese, nickel, selenium and zinc. The quality was within the SANS drinking water guidelines.
SW 5	Future monitoring point to replace SW 4	The quality was within the Sierra Leone legislative limits. Determinants elevated above the background quality include turbidity, nitrate, aluminium, iron, manganese and TSS. The aluminium concentration did however decrease by 50% between the August and October monitoring runs. The quality exceeded the Sierra Leone and SANS drinking water guidelines in terms of aluminium.
SW 6	G5 Dam upstream of future dry mining	This is the selected background water quality point. Quality is within the Sierra Leone legislative limits. Elevated compared to background quality in terms of nitrate, arsenic, iron and manganese. The quality was within the Sierra Leone and SANS drinking water guidelines.
SW 8	Gangama downstream, north of current dry mining	pH exceeded the Sierra Leone legislative limits in August. This was not measured in October. Elevated above background in terms of turbidity, nitrate, aluminium, chromium, iron, manganese and TSS. Aluminium exceeded the SANS drinking quality guidelines.
SW 9	Seepage under bridge at Nitti Port	Exceeded the Sierra Leone legislative limits for TSS in July, but within limit for August. Elevated above background in terms of EC, TDS, turbidity, chloride, sulfate, calcium, magnesium, aluminium, chromium, copper, selenium, zinc TSS and COD. Aluminium exceeded SANS drinking quality guidelines.
SW 12	Downstream of Bamba-Belebu Dredge Pond	Within the Sierra Leone legislative limits. Turbidity, sulfate and chloride were slightly elevated in August relative to the July and October. Turbidity exceeded the Sierra Leone and SANS drinking water guidelines in August.

Name	Location	Comment
SW 14	Downstream Mogbwemo and Titan/Motinga Ponds	pH exceeded the Sierra Leone legislative limits in August. This was not measured in October. Elevated above background in terms of turbidity, nitrate, manganese and zinc. TSS and arsenic were also elevated in July and August respectively, but dropped to comparable concentrations with the background in the subsequent monitoring period. Water quality is within the SANS drinking water guidelines.
SW 15	Mogbwemo Domestic Pond	pH exceeded the Sierra Leone legislative limits in July and August. This was not measured in October. Elevated above background in terms of turbidity, sulfate, nitrate, aluminium, manganese, selenium and zinc. Aluminium exceeded the SANS drinking water guidelines in August.
SW 17	Mogbwemo Dredge Pond near MSP upstream of Kpetema Bund	pH exceeded the Sierra Leone legislative limits in July and August. This was not measured in October. Elevated above background in terms of turbidity, sulfate, nitrate, aluminium, antimony, manganese, nickel and zinc. Aluminium exceeded the SANS drinking water guidelines.
SW18	Mogbwemo discharge to Pejebu Pond	pH exceeded the Sierra Leone legislative limits in August. This was not measured in July or October. Elevated above background in terms of turbidity, sulfate, aluminium, manganese, nickel, zinc and TSS. Aluminium exceeded the SANS drinking water guidelines.
SW19	Discharge from MSP Plant tailings into M6	pH exceeded the Sierra Leone legislative limits in August. This was not measured in July and October. This water is still reused in the plant and therefore even though the value exceeds the limits, the water is not discharged from site at this location. Elevated above background in terms of TSS, turbidity, sulfate, nitrate, aluminium, antimony, chromium, iron, manganese, nickel, zinc and TSS. Aluminium and iron exceeded the SANS drinking water guidelines.

The assessment indicates the following:

- There is a generally a low pH, and little mineral content for buffering. Therefore, there can be an expectation of mineralisation and solubilisation of some metals, including aluminium from the resident soils, which may occur naturally, and not necessarily directly caused by SRL operations. Whilst mining would usually be expected to impact surface water quality by disturbing the soils and ore bodies, on-going monitoring will better assist to assess natural influences on water quality versus mine related influences;
- It should be noted that a low pH of surface water samples with low mineral and salt content may be a natural reflection of the dissolution of carbon dioxide from the atmosphere, respiration of aquatic life forms and dissolution of natural soil humic acids etc. It does not necessarily infer that there is a direct detrimental impact of mining activities where not supported by significant changes in the ionic balance of the water;
- A slightly acidic pH of surface water samples similarly does not imply that the water quality is not fit-for-use, for domestic use or supporting aquatic life, particularly associated with weak acids such as carbonic acid from carbon dioxide. Future water quality monitoring should consider the specific concentration limits recommended in guidelines for water uses., This should also consider the context of the water use, which should be supported by aquatic biomonitoring, and understanding of the practical risk that the water quality parameters may pose, if any, to human health and the environment, in the context of the SRL operations;
- Mogbwemo Domestic Pond, although used by the local community as a domestic source of water, did not meet the drinking water quality guidelines in July and August due to the low pH (4.2 – 4.7) and elevated aluminium concentrations. The quality improved slightly in October with a drop in aluminium concentrations to within drinking water quality guideline limits. The pH was not measured in October;

- The water discharging from the MSP tailings, through to the Mogbwemo Dredge Pond is impacted by the mining activities. The pH is below the legislative limits and aluminium concentrations exceed the drinking water standard limits. The concentration of determinants appears to decrease at surface water locations further away from the MSP area;
- The impact from mining activities is far less obvious downstream of Bamba / Belebu Pond, as only slightly acidic (pH 5.8) conditions were noted in August at SW14. This is expected as there is no active mining occurring in this catchment;
- At the old mining areas of Pejebu, the dam and dredge pond water quality is comparable to the background water quality, except the acidity that exceeds the legislative limits (pH of 4.5 at the dredge pond and pH 5.9 at the dam). The quality does not comply with the legislation limits due to the low pH but is within the drinking water quality guideline limits. This point is a recipient of the MSP effluent;
- The surface water quality is within the legislative limits at Lanti, except pH that exceeded the limits in August. The determinants elevated above background levels include TSS, turbidity, sulfate, nitrate, manganese, nickel, selenium and zinc. Aluminium concentrations are elevated relative to the drinking water guideline limits and the pH is also below the drinking water guidelines limit;
- At Gangama operations, the quality of G5 dam water is comparable to the background water quality except nitrate concentrations that are slightly elevated relative to the background levels. Further down gradient from the Plant area, the water quality appears to be impact by mining activities indicated by acidity (pH of 5.8) and elevated dissolved aluminium content; and
- Nitti Port surface water has elevated aluminium, chloride and magnesium concentrations relative to the background levels and consequently increased salinity (EC and TDS). Aluminium concentrations exceed the drinking guidelines limits.

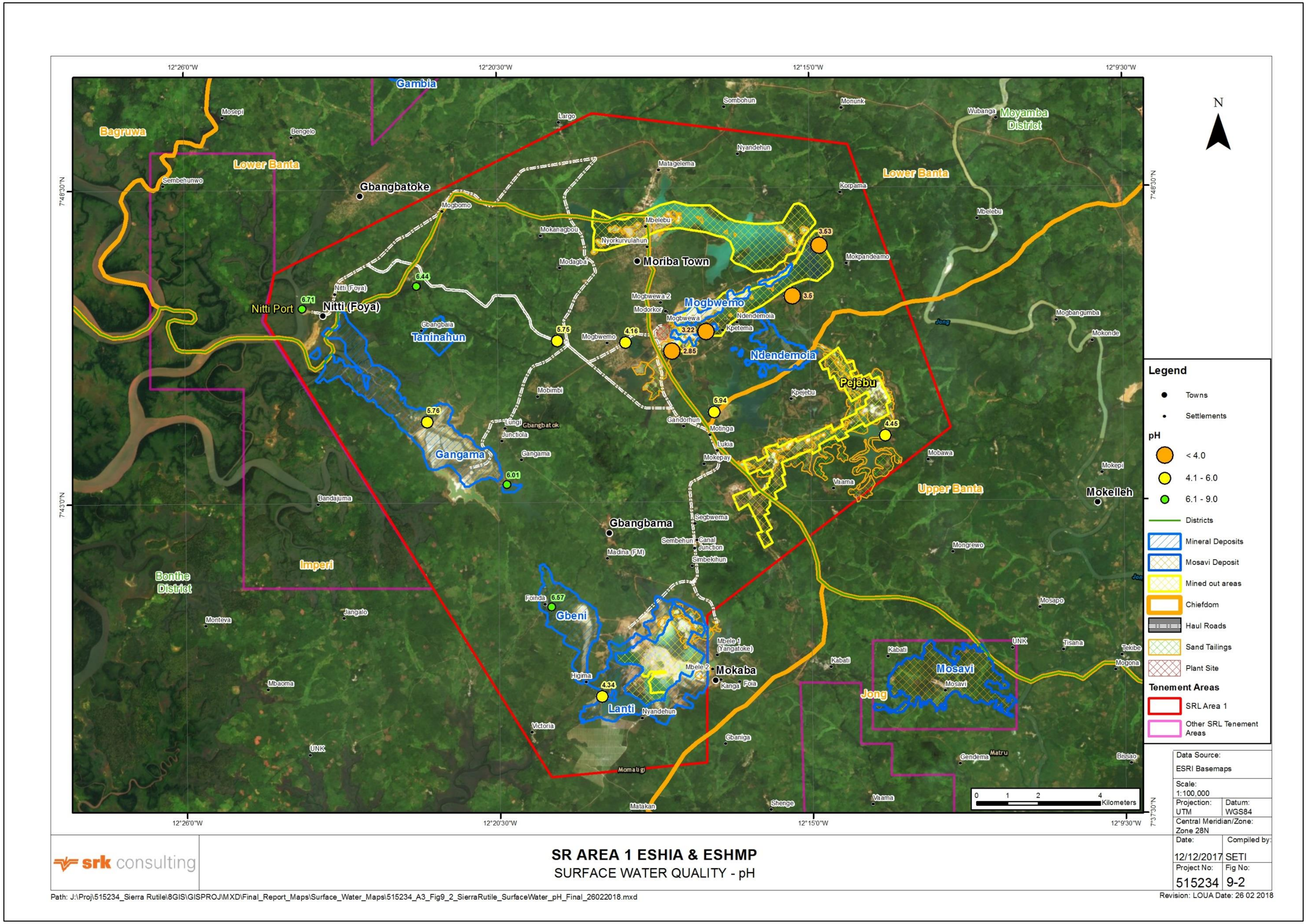


Figure 9-2: Surface water quality – pH (August 2017 dataset)

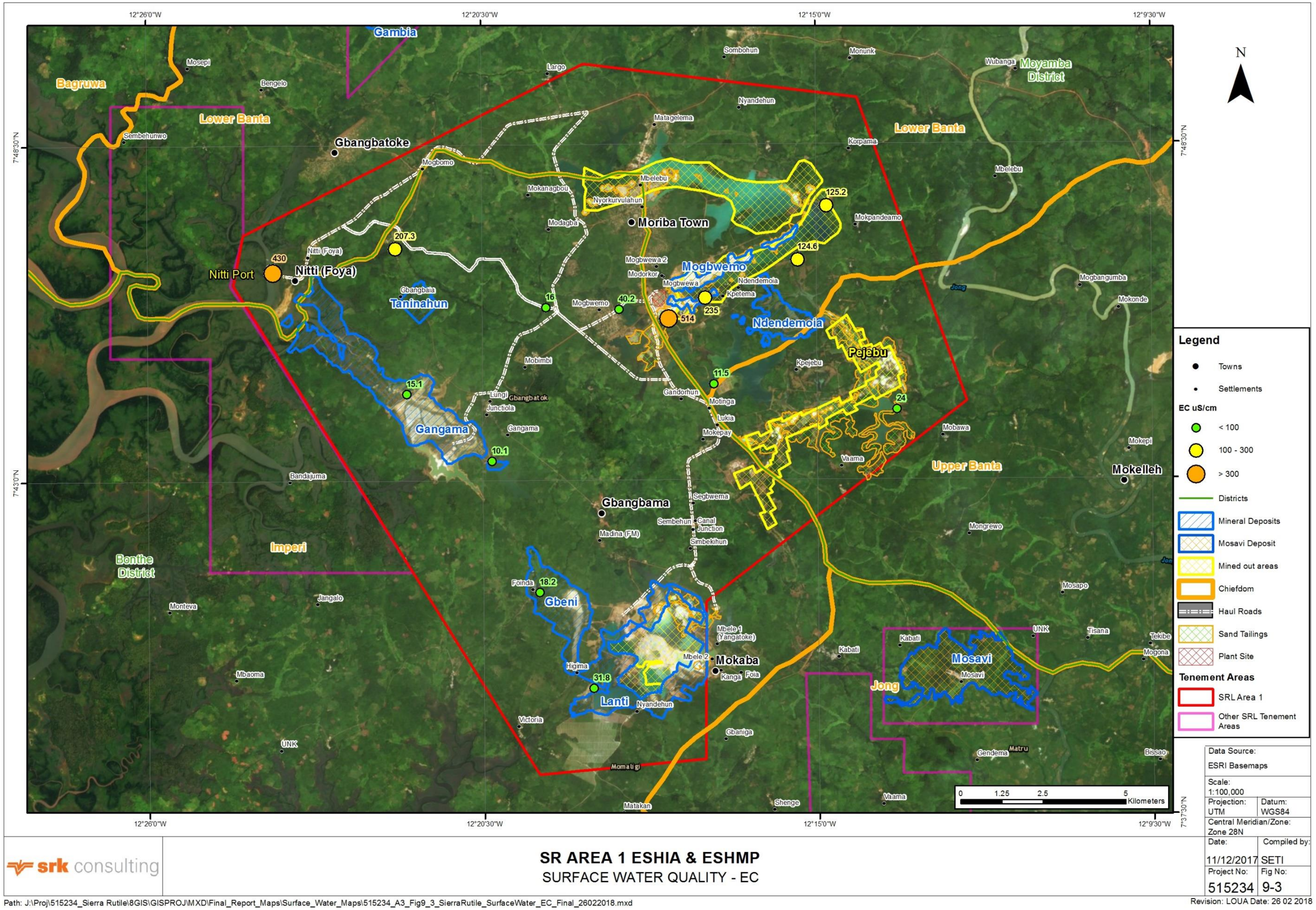


Figure 9-3: Surface water quality – EC (August 2017 dataset)

10 Pond Water Levels

Water levels of the Area 1 ponds have been monitored over time as the water availability is critical in the dredge mining process. The dataset spans from late December 2016 to mid-July 2017, and was plotted over time and against the rainfall data available for the various areas to evaluate reasons for decline or rise in water levels over time and to identify seasonal trends. The crest and freeboard levels are indicated on the various plots as markers. The source of this file showing the freeboard requirements was sent to SRK by SRL (Microsoft Excel spreadsheet called 'Daily Pond Level Measurements Critical Ponds new').

10.1 Gangama DM 2

The Gangama pond area is located in the western region of the Area 1. The water flow between the dams is indicated in Figure 10-1.

During the analysis of the data, it became apparent that there is a discrepancy in the datasets for Gangama operations:

- There is a notable decline in water level data for G6 Dam on the 28th of March 2017, which correlates to a marked increase in water levels in G7 Dam the following two days;
- The data for Dam G6 indicates a strong correlation to G7 and when the water levels are high, they are essentially the same dam along with G4 Dam;
- Dam G4 has a spillway that allows water to flow via gravity flow into G7 Dam; and
- The flow diagram illustrated in Figure 10-1 indicates that water from Dam G4/G6 is directed to G7 Dam to ensure sufficient quantities are supplied to the plant.

The above points suggest that the data captured for G4 Dam and G6 Dam are likely switched. The following interpretation of the pond water levels takes this assumption into account.

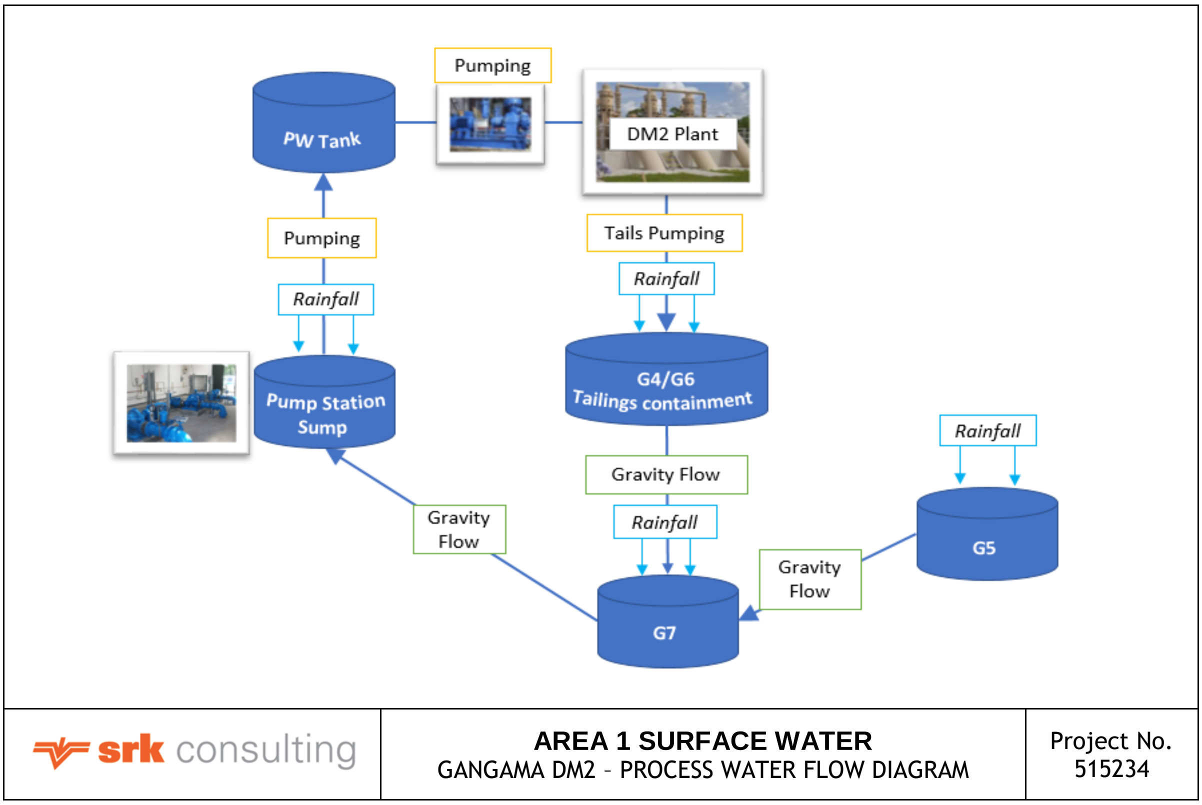
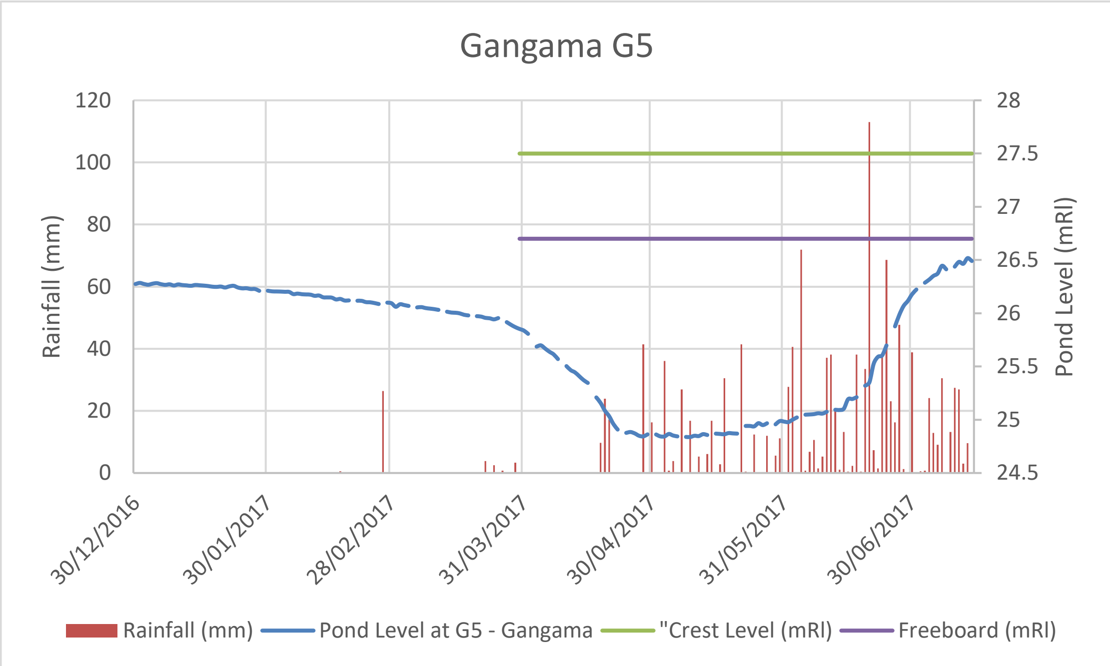


Figure 10-1: DM2 Gangama process water flow diagram.

10.1.1 G5 Dam water levels

Water levels in the G5 pond have been monitored from late December 2016 and are plotted below in Figure 10-2. About 90 mm of rainfall fell by 20 April 2017 which resulted in a significant decline in water levels noted, which stabilised at this level until late May 2017. About 300 mm of rainfall fell during the end of May, before increase in water level occurred. Thereafter, 700 mm fell which resulted in the quick increase from mid-July 2017. Water flows from G5 into G7 (Figure 10-1) through a spillway as well as a siphon via gravity flow. The spillways should be sized to convey the 1:100 year Return Period storm in order to ensure that the freeboard requirements are met and that the dams are within the dam safety protocols.



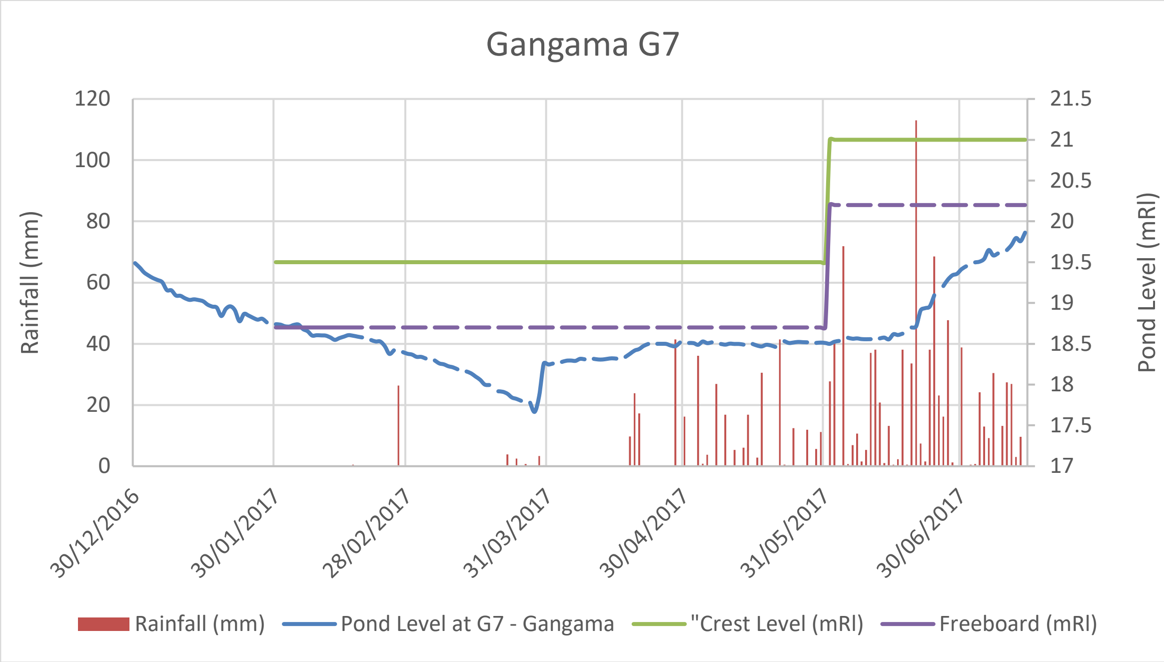
srk consulting	AREA 1 SURFACE WATER GANGAMA G5 POND WATER LEVEL TIME PLOT AGAINST RAINFALL	Project No. 515234

Figure 10-2: Gangama G5 pond water level time plot against rainfall

10.1.2 G7 Dam water levels

Figure 10-3 indicates the plot of water levels for pond G7 against rainfall over time. On the 28th to the 30th of March 2017 there was a notable increase in water levels in the pond, and this corresponds to the decline in water levels noted in the G6 Dam in Section 10.1.3. There is a gradual increase of the water level to and stabilized at 18.5 mRI for the duration of May 2017. From mid-June to mid-July 2017 there was 586 mm of rain that fell in the area, resulting in the rapid increase of the water level during this time.

Water from G7 Dam flows to the pump station by gravity flow. The pump station articulates water to the process water tank for storage. The Wet Concentration Plant (WCP) receives its water from the process water (PW) tank and the effluent and tailings is pumped to the G4 and G6 Dams. The WCP's main source of water is from the G7 Dam, which is at the lowest elevation.

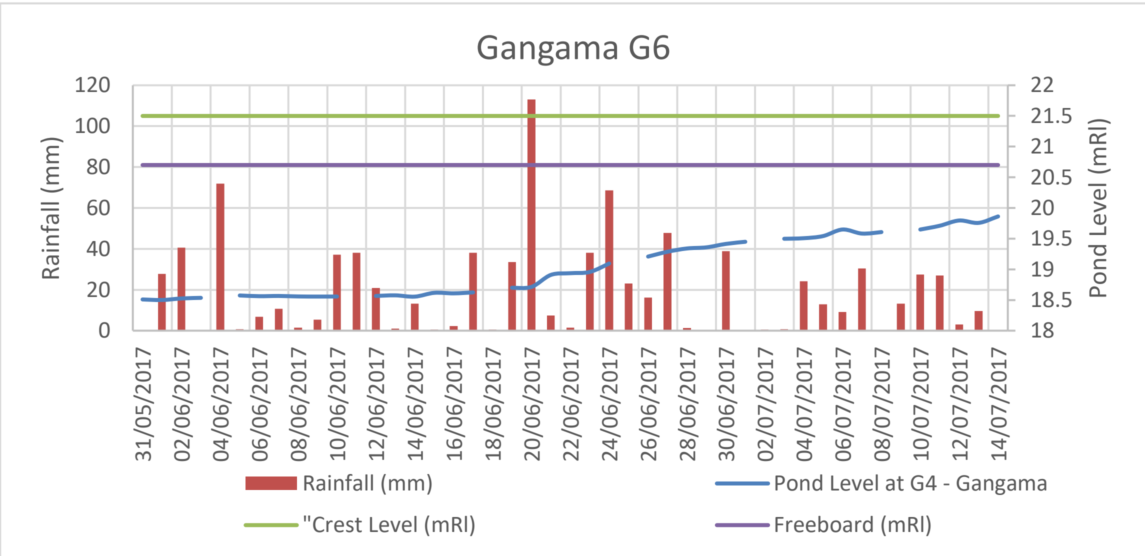


srk consulting	**AREA 1 SURFACE WATER** GANGAMA G7 POND WATER LEVEL TIME PLOT AGAINST RAINFALL	Project No. 515234

Figure 10-3: Gangama G7 pond water level time plot against rainfall

10.1.3 G6 Dam water levels

G6 Dam receives water via pumping from the DM2 WCP, and monitoring at G6 was undertaken from mid-May 2017 and is plotted in Figure 10-4. The data indicates that there was general stability of the water levels for the first half of June with slight variations in the water level, followed by an increasing trend for the remainder of June through to July 2017. This increasing trend is a result of an increased rainfall of 262 mm from the 20 June to the 24 June, followed by runoff and flow from the upstream catchment. The water levels in this dam is controlled by the DM 2 Plant and G4 overflow.

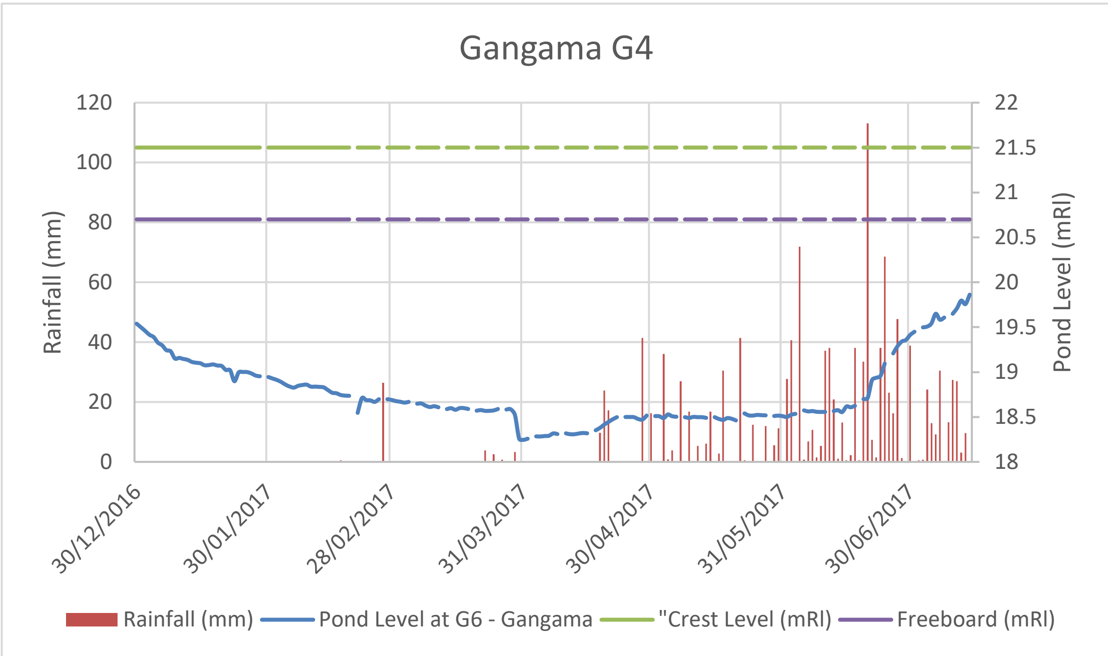


srk consulting	**AREA 1 SURFACE WATER** G6 POND WATER LEVELS	Project No. 515234

Figure 10-4: Gangama G6 pond water level time plot against rainfall

10.1.4 G4 Dam water levels

G4 Dam receives water that is being pumped from the DM 2 Plant from tailings. G4 Dam spills into G7 Dam via gravity flow, as well as into the environment at the G4 Dam wall. Water levels in the G4 Dam have been monitored from late December 2016 and are plotted below in Figure 10-5. There was a gradual decline in water levels from December through to mid-June, with a steep, but small decline occurring at the end of March 2017. This decline could be attributed to water being released from the G4 Dam into G7 Dam. The water levels rose slightly over April and stabilised for the duration of May and into June 2017 with only 600 mm falling over the first half of the year. With the rains occurring over May and into June adding an additional 620 mm over this period, the water levels in G6 Dam rose as flow from the upstream catchment come through. The G4 Dam spillway started flowing in June 2017.



srk consulting	**AREA 1 SURFACE WATER** G4 POND WATER LEVELS	Project No. 515234

Figure 10-5: Gangama G4 pond water level time plot against rainfall

10.2 Mineral Separation Plant

The MSP is located on an elevated area and therefore pumping water between dams occurs more than gravity flow. Only two dams in this area are currently being monitored for water levels, the TT Pond and the Construction Yard Pond. The TT Pond receives water via pumping from the MSP, and from there is transferred to the Construction Yard Pond, as seen in Figure 10-6.

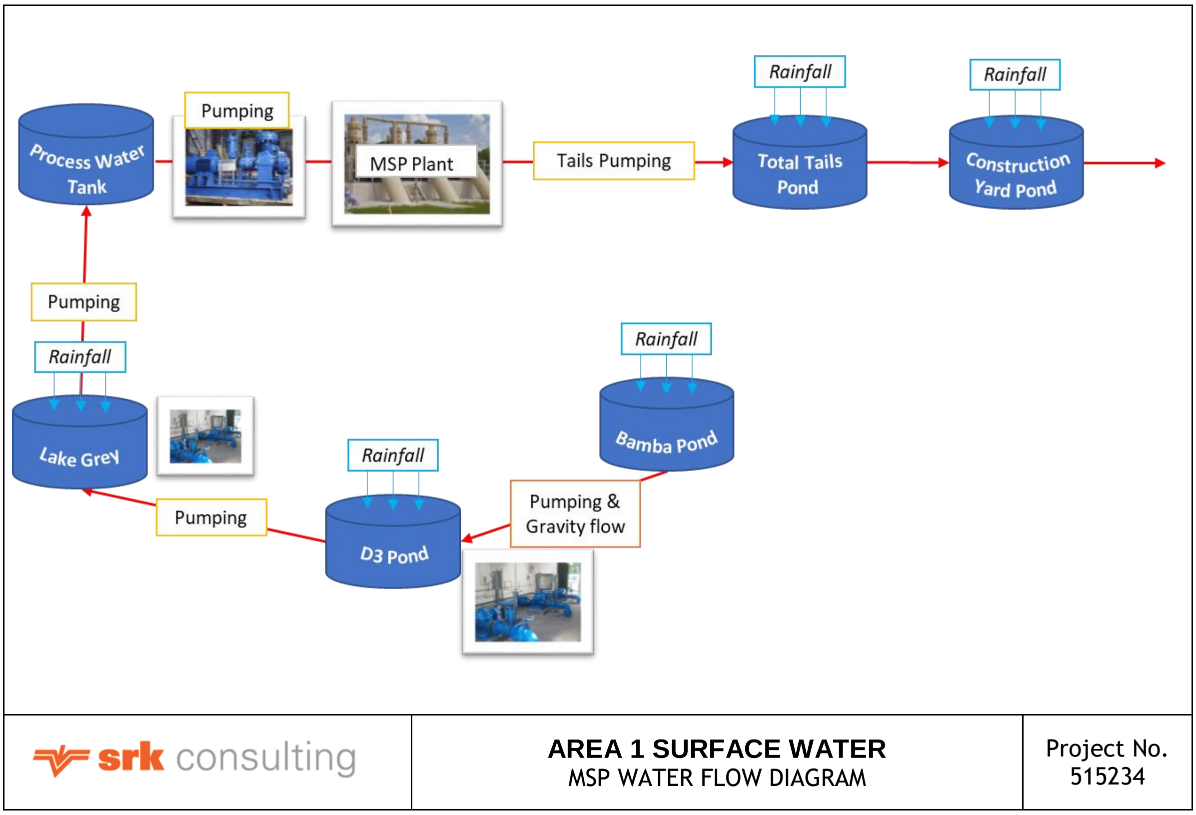


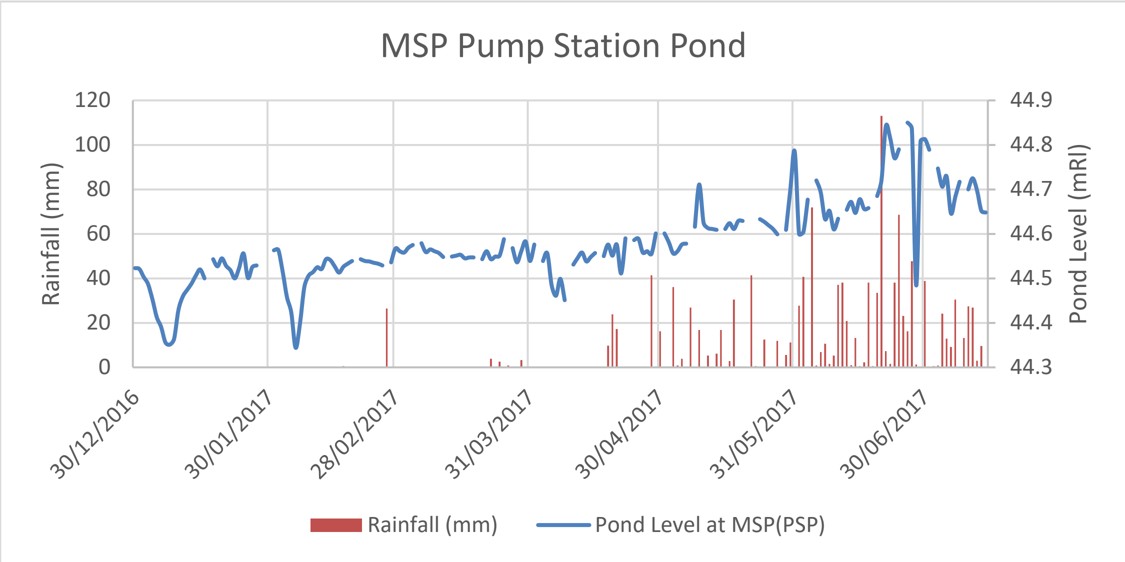
Figure 10-6: MSP water flow diagram

10.2.1 Mogbwemo/Titan/Motinga Ponds connectivity

The links between the Motinga Pond, Titan Pond and Mogbwemo Domestic Reservoir are not always evident but they are connected when the water levels are high in the impoundments. The Motinga Pond usually flows into the Pejebu Pond but at high water levels, there is also a channel that flows towards the Titan Pond, which can also overflow into the Mogbwemo Domestic Reservoir. The Mogbwemo Domestic Reservoir discharges water into an unnamed tributary of the Yambei River.

10.2.2 Construction Yard Pond

This pond receives water input from the Total Tailings Pond, as well as rainfall. Water level data has been captured for this pond from late December 2016 to late July 2017. The water level variation trend is similar to that of the Total Tails Pond described in Section 10.2.1. The data shows a strong correlation to rainfall events, indicating the ponds susceptibility to climate as well as the variation in volumes pumped from the MSP Plant.



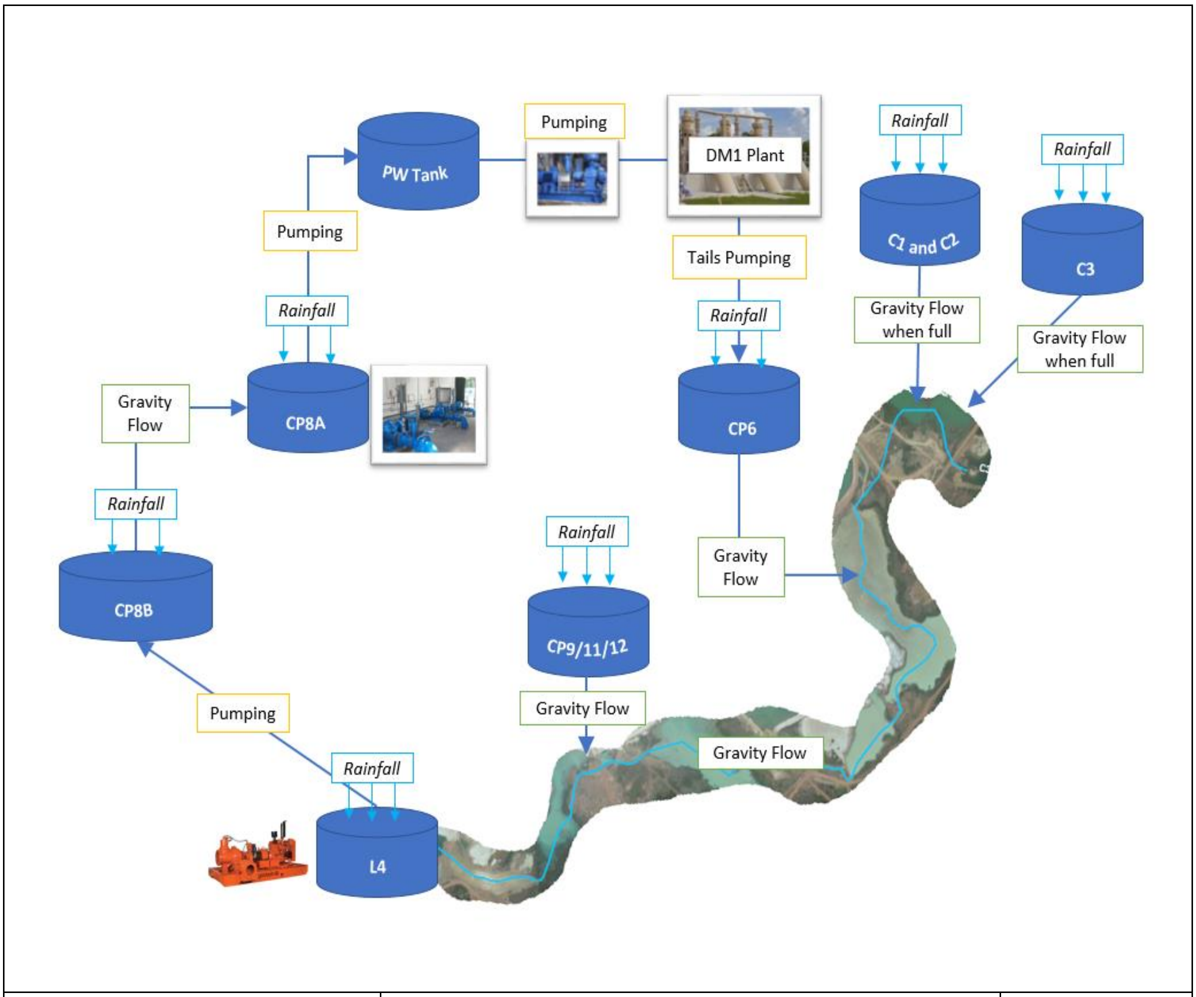
srk consulting | **AREA 1 SURFACE WATER** CONSTRUCTION YARD POND WATER LEVELS | Project No. 515234

Figure 10-7: Construction Yard pond water level time plot against rainfall

10.3 Lanti (DM1)

The Lanti DM1 area ponds are governed by gravity flow, as can be seen in the water flow diagram in Figure 10-8. Pumping only occurs within the area of the PW Tank and DM1 plant site.

Water in the ponds CP9A, CP9B and CP12, which is directly connected with CP11, were monitored from the 30 December 2016.



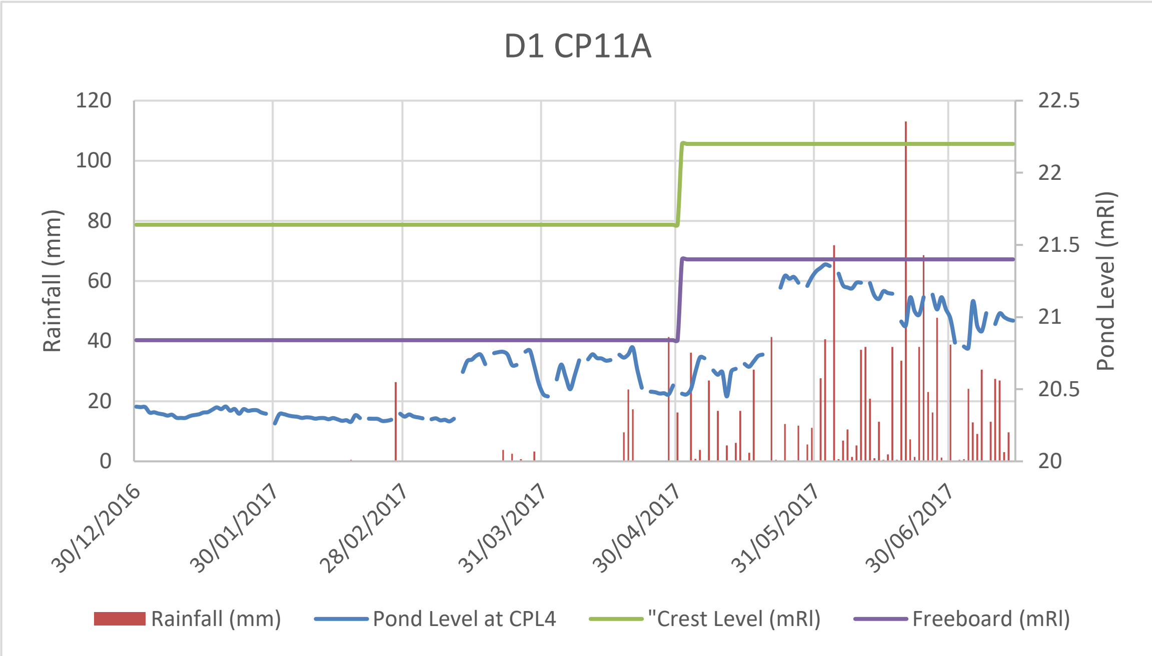
srk consulting	**AREA 1 SURFACE WATER** LANTI DM 1 WATER FLOW DIAGRAM	Project No. 515234

Figure 10-8: Lanti DM1 water flow diagram

10.3.1 CP11A Pond water levels

Water levels have been monitored in Lanti CP11A Pond since late December 2016 and show a steady water level of around 20 mRl, for the first quarter of 2017. There was an increase of approximately 0.4 m in the water level on the 13 March 2017, where continued monitoring indicated water level variations of about 0.2 m occurring over the next few months in mid-May 2017. At the end of April 2017, the crest level of the pond was elevated to accommodate the upcoming rainy season inflows into CP11A Pond, which also resulted in the freeboard level increase.

Rainfall began in earnest at the end of April to early May 2017, where approximately 200 mm fell, resulting in water level rise in the pond even though this is always managed by decanting throughout this period, with the objective to not breach the freeboard requirement being paramount. By the start of June 2017, the water level in CP11A Pond had reached just below the freeboard elevation. Mitigation measures for the pond were undertaken, resulting in a gradual decrease in the water level to provide sufficient buffer to the freeboard elevation.



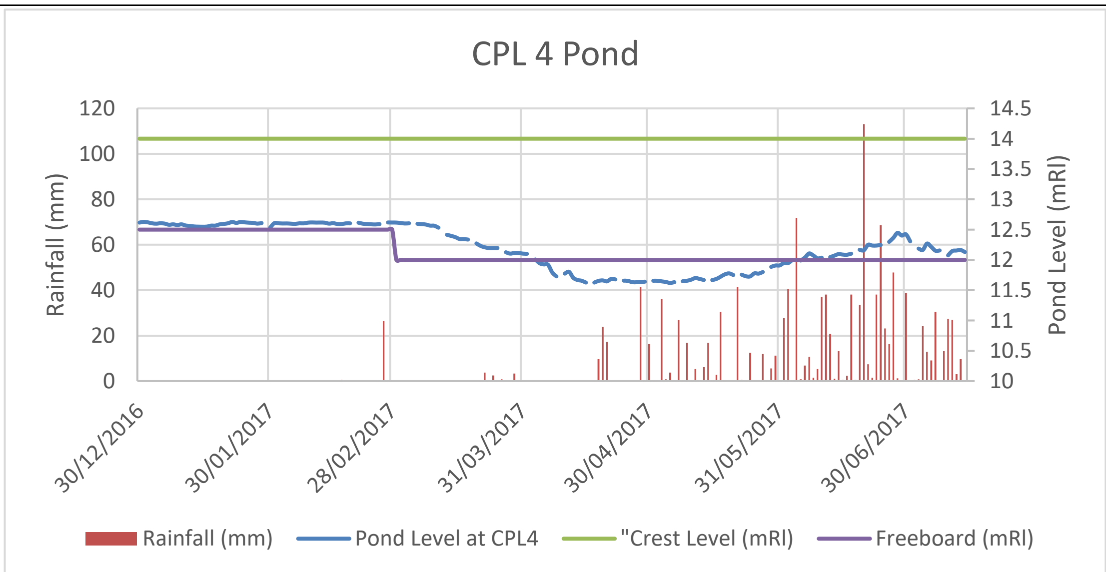
AREA 1 SURFACE WATER
DM1 CP11A POND WATER LEVELS

Project No.
515234

Figure 10-9: Lanti DM1 CP11A Pond water level time plot against rainfall

10.3.2 CPL4 Pond water levels

Water levels in CPL4 Pond were above the freeboard since commencement of monitoring in late-December 2016. At the end of February 2017, the original spillway level was re-instated, with the water level thereby decreasing over the next few weeks. The water level was successfully lowered below the freeboard elevation at the start of April 2017. It remained constant until mid-May, where is began to rise due to the accumulated rainfall over a two-month period of 895 mm. By early-June 2017 the water levels were once again above freeboard elevation causing the spillway to flow once again.



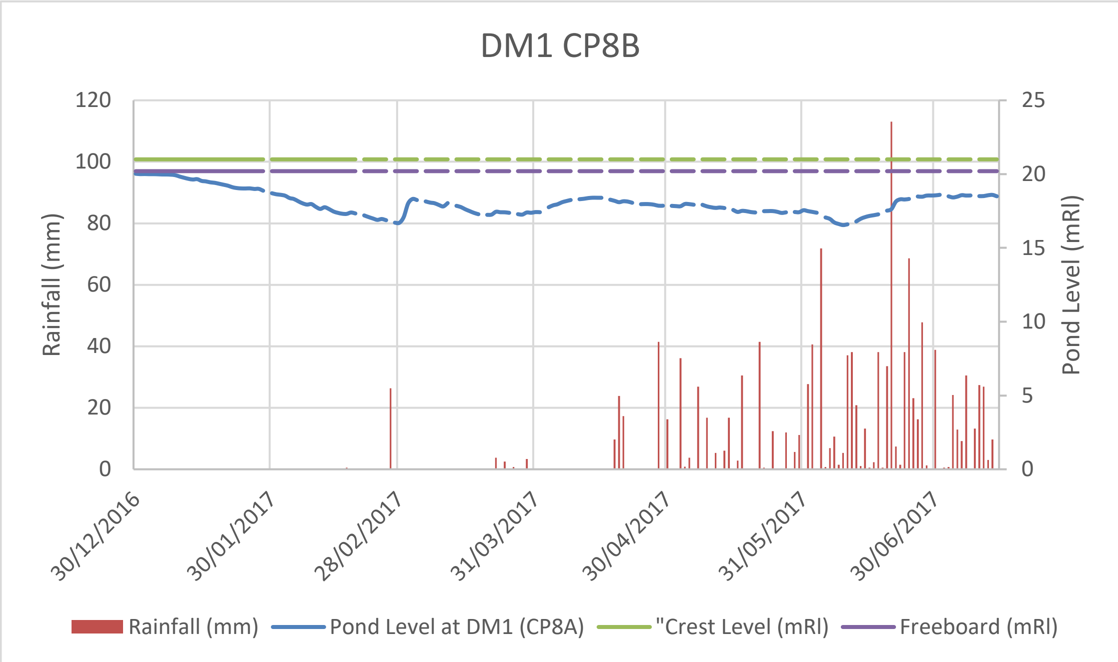
AREA 1 SURFACE WATER
DM1 CPL4 POND WATER LEVELS

Project No.
515234

Figure 10-10: Lanti DM1 CLP4 Pond water level time plot against rainfall

10.3.3 CP8B Pond water levels

Lanti DM1 CP8B pond water levels have been well maintained below the freeboard elevation for the duration of the monitoring since December 2016. There is a noted increase in the water level that occurred at the same time as the decline in freeboard in CPL4 Pond, indicating the controlled release of water from the CPL4 Pond which flowed to CP8B Pond via pumping. The water level data for the high rainfall events that occurred during May and June 2017 indicate a controlled increasing trend, and eventual stability towards the end of July 2017.



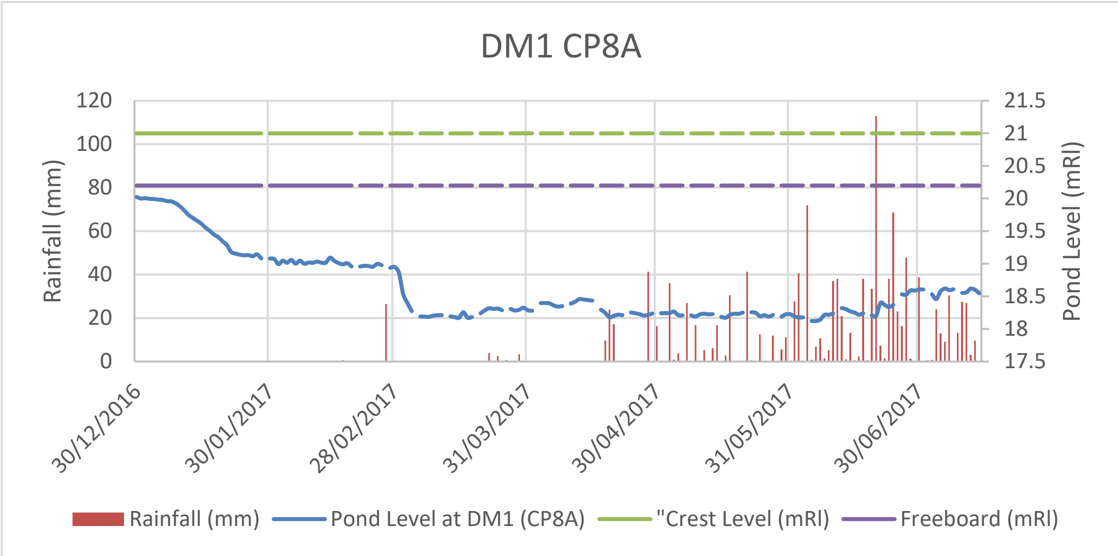
srk consulting	AREA 1 SURFACE WATER DM1 CP8A POND WATER LEVELS	Project No. 515234

Figure 10-11: Lanti DM1 CP8B pond water level time plot against rainfall

10.3.4 CP8A Pond water levels

CP8A Pond receives gravity flow from the CP8B Pond and water from this pond is pumped to the PW Tank for the Lanti DM1 Plant use. It is evident in the monitoring data that the flow from CP8B Pond was significantly diminished for the month of January 2017, as well as pumping of water to the PW Tank, resulting in an initial steep decline in water level because production was ceased for a period. Flow was restored at the end of January through to the end of February 2017 where water levels stabilised.

The water levels in this pond were well maintained during the high rainfall events and season, resulting in a ± 0.5 mRl increase by the end of July 2017.

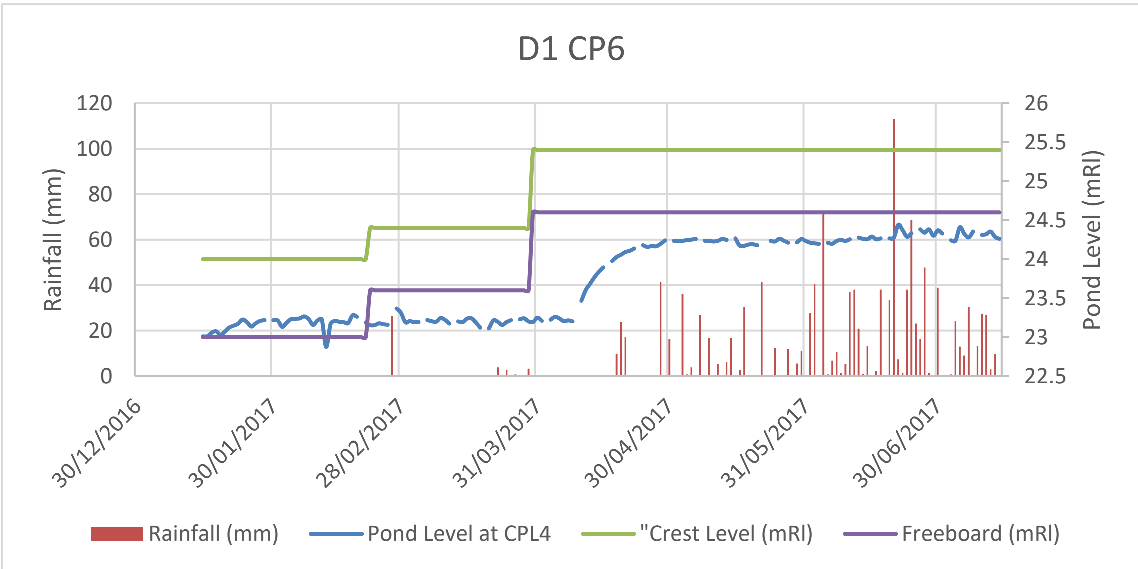


srk consulting	**AREA 1 SURFACE WATER** DM1 CP8A POND WATER LEVELS	Project No. 515234

Figure 10-12: Lanti DM1 CP8A pond water level time plot against rainfall

10.3.5 CP6 Tailings Pond water levels

The CP6 Pond closes the DM1 circuit by receiving water from the DM1 WCP via pumping, and releasing overflow via gravity to the water course directed towards L4 Dam. Water levels in Pond CP6 were above the freeboard from early January 2017, until the dam height was increased. The water levels maintained a general level around 23.35 mRl until early-April 2017. Another increase in the height of the dam was undertaken at the end of March to allow for further capacity from the plant. Once construction was finalised, a large storm ensued and the decant was not managed sufficiently, resulting in a rapid rise in the water level, only stabilising at the beginning of May 2017, where it was maintained. A slight increase in the water level is noted after the high rainfall event that occurred on the 20th of June 2017, where 113 mm fell. The levels were quickly brought under control and stabilised around 24.3 mRl.



srk consulting	**AREA 1 SURFACE WATER** DM1 CP6 POND WATER LEVELS	Project No. 515234

Figure 10-13: DM1 CP6 pond water level time plot against rainfall

11 Impact Assessment

11.1 Impact assessment methodology

The impact assessment was conducted in an integrated manner that links the biophysical components with the socio-economic components of the environment. The impact assessment is divided into issue identification, impact definition, and impact evaluation. Iteration of these parts occurs in each stage of an ESHIA process to varying degrees.

All specialists working on the ESHIA will use a common, systematic and defensible method of assessing significance that will enable comparisons to be made between impacts across different disciplines. It will also enable all relevant parties to understand the process and rationale upon which impacts have been assessed.

Generally, the impact assessment is divided into three parts:

- **Issue identification** - each specialist will be required to evaluate the ‘aspects’ arising from the project description and ensure that all issues in their area of expertise have been identified;
- **Impact definition** - positive and negative impacts associated with these issues (and any others not included) will then be defined. The definition statement will include the activity (source of impact), aspect and receptor as well as whether the impact is direct, indirect or cumulative. Fatal flaws should also be identified at this stage; and
- **Impact evaluation** – this is not a purely objective and quantitative exercise. It has a subjective element, often using judgement and values as much as science-based criteria and standards. The need therefore exists to clearly explain how impacts have been interpreted so that others can see the weight attached to different factors and can understand the rationale of the assessment.

The basic elements used in the evaluation of impact significance are described in Table 11-1 and the characteristics that are used to describe the consequence of an impact are outlined in Table 11-2.

Table 11-1: Key elements in the evaluation of impact significance

Element	Description	Questions applied to the test of significance
Consequence	An impact or effect is described as the change in an environmental parameter, which results from a particular project activity or intervention. Here, the term "consequence" refers to: (a) The sensitivity of the receiving environment, including its capacity to accommodate the kinds of changes the project may bring about. (b) The type of change and the key characteristics of the change (these are magnitude, extent and duration). (c) The importance of the change (the level of public concern/ value attached to environment by the stakeholders and the change effected by the project). The following should be considered in the determination of impact consequence: (a) Standards and guidelines (thresholds). (b) Scientific evidence and professional judgment. (c) Points of reference from comparable cases. (d) Levels of stakeholder concern.	Will there be a change in the biophysical and/or social environment? Is the change of consequence (of any importance)?
Probability	Likelihood/chance of an impact occurring.	What is the likelihood of the change occurring?
Effectiveness of the management measures	Significance of the impact needs to be determined both without management measures and with management measures. The significance of the unmanaged impact needs to be determined so there is an appreciation of what could occur in the absence of management measures and of the effectiveness of the proposed management measures.	Will the management measures reduce impact to an acceptable level?
Uncertainty/ Confidence	Relating to uncertainty in impact prediction and the effectiveness of the proposed management measures. Sources of uncertainty in impact prediction include: (a) Scientific uncertainty – limited understanding of an ecosystem (or affected stakeholders) and the processes that govern change. (b) Data uncertainty – restrictions introduced by incomplete, contradictory or incomparable information, or by insufficient measurement techniques. (c) Policy uncertainty – unclear or disputed objectives, standards or guidelines. There are a number of approaches that can be used to address uncertainty in impact prediction, including: (a) 'Best' and 'worst' case prediction to illustrate the spread of uncertainty. (b) Attaching confidence limits to impact predictions. (c) Sensitivity analysis to determine the effect of small changes in impact magnitude.	What is the degree of confidence in the significance ascribed to the impact?

Table 11-2: Impact assessment methodology characteristics

Characteristics used to describe consequence	Sub-components	Terms used to describe the characteristic
Type		Biophysical, social or economic
Nature		Direct or indirect, cumulative etc.
Status		Positive (a benefit), negative (a cost) or neutral
Phase of project		During pre-construction (if applicable e.g. resettlement), construction, operation, decommissioning/post closure
Timing		Immediate, delayed
Magnitude	**Sensitivity** of the receiving environment / receptors	High, medium or low sensitivity Low capacity to accommodate the change (impact)/ tolerant of the proposed change
	Severity/ intensity (degree of change measured against thresholds and/or professional judgment)	Gravity / seriousness of the impact Intensity/ influence / power / strength
	Level of stakeholder concern	High, medium or low levels of concern All or some stakeholders are concerned about the change
Spatial extent or population affected The area / population affected by the impact The boundaries at local and regional extents will be different for biophysical and social impacts		Area / volume covered, distribution, population Site / local (social impacts should distinguish between site and local), regional, national or international
Duration (and reversibility) Length of time over which an impact occurs and potential for recovery of the endpoint from the impact		Short term, long term Intermittent, continuous Reversible / irreversibility Temporary, permanent
Confidence Based on information available and competencies of the assessor		High, Medium, Low

The impact significance rating process serves two purposes: firstly, it helps to highlight the critical environmental and social impacts requiring consideration in the management and approval process; secondly, it serves to show the primary impact characteristics, as defined above, used to evaluate impact significance.

The impact significance rating system is presented in Table 11-3 and involves four parts:

- **Part A:** Define the impact consequence using the three primary impact characteristics of magnitude, spatial scale/population and duration;
- **Part B:** Use the matrix to determine a rating for impact consequence based on the definitions identified in Part A;
- **Part C:** Use the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from Part B) and the probability of occurrence; and
- **Part D:** Define the Confidence level.

Table 11-3: Impact assessment significance rating

PART A: DEFINING CONSEQUENCE IN TERMS OF MAGNITUDE, DURATION AND SPATIAL SCALE
Use these definitions to define the consequence in Part B

Impact characteristics	Definition	Criteria
MAGNITUDE	Major	Substantial deterioration or harm to receptors; receiving environment has an inherent value to stakeholders; receptors of impact are of conservation importance; or identified threshold often exceeded.
MAGNITUDE	Moderate	Moderate/measurable deterioration or harm to receptors; receiving environment moderately sensitive; or identified threshold occasionally exceeded.
MAGNITUDE	Minor	Minor deterioration (nuisance or minor deterioration) or harm to receptors; change to receiving environment not measurable; or identified threshold never exceeded.
MAGNITUDE	Minor+	Minor improvement; change not measurable; or threshold never exceeded.
MAGNITUDE	Moderate+	Moderate improvement; within or better than the threshold; or no observed reaction.
MAGNITUDE	Major+	Substantial improvement; within or better than the threshold; or favourable publicity.
SPATIAL SCALE OR POPULATION	Site or local	Site specific or confined to the immediate project area.
SPATIAL SCALE OR POPULATION	Regional	May be defined in various ways, e.g. cadastral, catchment, topographic.
SPATIAL SCALE OR POPULATION	National/ International	Nationally or beyond.
DURATION	Short term	Up to 12 months.
DURATION	Medium term	12 months to 5 years
DURATION	Long term	Longer than 5 years

PART B: DETERMINING CONSEQUENCE RATING
Rate consequence based on definition of magnitude, spatial extent and duration

			SPATIAL SCALE/ POPULATION		
			Site or Local	Regional	National/ international
MAGNITUDE					
Minor	DURATION	Long term	Medium	Medium	High
Minor	DURATION	Medium term	Low	Low	Medium
Minor	DURATION	Short term	Low	Low	Medium
Moderate	DURATION	Long term	Medium	High	High
Moderate	DURATION	Medium term	Medium	Medium	High
Moderate	DURATION	Short term	Low	Medium	Medium
Major	DURATION	Long term	High	High	High
Major	DURATION	Medium term	Medium	Medium	High
Major	DURATION	Short term	Medium	Medium	High

PART C: DETERMINING SIGNIFICANCE RATING
Rate significance based on consequence and probability

		CONSEQUENCE		
		Low	Medium	High
PROBABILITY (of exposure to impacts)	Definite	Medium	Medium	High
PROBABILITY (of exposure to impacts)	Possible	Low	Medium	High
PROBABILITY (of exposure to impacts)	Unlikely	Low	Low	Medium

PART D: CONFIDENCE LEVEL

High	Medium	Low

Practical management measures and recommendations and post management significance will be listed, using a GIIP management hierarchy in that:

"Recommendations for management should focus on avoidance, and if avoidance is not possible, then to reduce, restore, compensate/offset negative impacts, enhance positive impacts and assist project design."

The significance of impacts will be re-assessed with assumed management measures in place ("after management"). Specialists will also recommend and describe appropriate monitoring and review programs to track the efficacy of management measures. These will be included as management and / or action plans.

An example of the table used to report the significance rating for each impact before and after the implementation of mitigation / management measures, and listing these measures, is provided in Table 11-4.

Table 11-4: Example of impact significance rating and mitigation measures

Impact xx: Habitat disturbance resulting in invasion by exotic fauna and flora								
	Magnitude	**Duration**	**Scale**	**Consequence**	**Probability**	**Significance**	**+ /-**	**Confidence**
Before Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Possible***	***Medium***	-	*Medium*
Management Measures:								
After Management	*Minor*	*Short term*	*Site / local*	***Low***	***Unlikely***	***Low***	-	*Medium*

11.2 Potential impacts on water resources

The following potential impacts are envisaged from the Surface Water Specialist Study (SSWS):

- **Impact SWSS 1:** Construction of dams and ponds attenuate flood peaks resulting in changes in seasonal flooding patterns which affect sediment loading, sediment deposition on floodplains, fish ecosystem and local communities/ residents;
- **Impact SWSS 2:** Increase in flooding in the pit due to lack of stormwater diversion from the Gbeni operations causing an impact on operations;
- **Impact SWSS 3:** Decrease in water quality downstream of the Gangama and Gbeni operations due to inadequate stormwater management;
- **Impact SWSS 4:** Dam walls being overtopped or failing as a result of freeboard requirements not being sufficient and a large flood event occurs;
- **Impact SWSS 5:** Insufficient water for mining and processing at Lanti operations and MSP;
- **Impact SWSS 6:** Excess water release may affect downstream users from Gangama operation;
- **Impact SWSS 7:** Discharge of acidic water from the MSP and Lanti operation leading to reduction in pH and increased acidity resulting in acidic, soft and corrosive water affecting the natural water system; and
- **Impact SWSS 8:** Potential use of acidic, soft and corrosive water at Lanti Dry Mine process plant resulting in corrosion and damage of metallic structures, equipment and pipes.

11.3 Impact ratings and management measures

Impact SWSS 1: Construction of dams and ponds attenuate flood peaks resulting in changes in seasonal flooding patterns which effect sediment loading, sediment deposition on floodplains, fish ecosystems and local communities/ residents

The current and historical dredge ponds created through the dredge mining operations are used to supply domestic and process water for the mine facilities and for agricultural operations. SRL and its predecessor have constructed 28 dams to impound water at the site. Of these 28 dams, 14 of the dam walls exceed 15 m in height meaning that they impound a large volume of water and therefore severely attenuate the flood peaks. These dams are regularly inspected.

SRL dams and ponds play important role in attenuating the flooding effect into the workings and as water storage for mine sites. Local communities currently use the old dredge ponds as a domestic water source even though access and usage is prohibited. The dredge ponds and reservoirs were created by construction of engineered earthen embankments designed and positioned to collect base flow, runoff, and precipitation resulting in inundation of some areas underlain by the rutile deposits.

Construction of the dredge ponds and dams in local site drainages results in changes in seasonal flooding patterns of the affected rivers, which affect sediment loading, sediment deposition on floodplains, aquatic ecosystems and local communities / residents.

Seasonal River Flow

Ponds and dams have altered river flow dynamics in downstream receiving waters which has caused an environmental impact on the natural functioning of the river system. Life in and around a river evolves and is conditioned on the timing and quantities of river flow. Disrupted and altered water flows can be as severe as completely de-watering river reaches and the life they contain during low flows.

Sediment loading

Sediment loading in a river helps to reduce the river bed and bank erosion which may weaken riverbank structures, infrastructure and riparian forests along the riverside. Sediment loading in river systems is critical for maintaining physical processes and the habitats downstream of the dam (these habitats include the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands).

Sediment deposition on floodplains

The presence of the dams will reduce flood peaks and therefore, the seasonal flooding of the floodplains adjacent to the river channel. This will in return reduce the fertility of the areas adjacent to the river channel as the nutrient rich soil, from upstream areas, is no longer deposited there. This nutrient rich soil also causes the sedimentation of the dams and reduces their capacity. This will be covered further in future soil scientist specialist studies.

Fish ecosystems

The impacts of the fish ecosystems will be covered further in the estuarine and river health specialist studies.

Local communities/residents

The impact of water on the communities is covered further in the social specialist studies.

Table 11-5: Impact SWSS 1 - Construction of dams and ponds attenuate high flood peaks resulting in changes in seasonal flooding patterns which effect sediment loading, sediment deposition on floodplains, fish ecosystems and local communities/ residents

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ / -	Confidence
Before Management	*Major*	*Long term*	*Regional*	***High***	***Definite***	***High***	-	*High*
Management Measures: • Investigate the removal of the dams to allow the natural functioning of the ecosystems in accordance with the Mine Closure Plan; and • SRL should review the reservoir hydrology and spillway design depending on the closure plan recommendations regarding the dams.								
After Management	*Major*	*Long term*	*Regional*	***High***	***Definite***	***High***	+	*Medium*

Once the dams are removed, the functioning of the river and ecosystems will begin to recover and the effect would be a long term **positive** result. The only negative result that removing the dams would have, would be on the livelihoods of those who have adjusted their livelihoods due to the proximity and the resources that become available with the dams. The removal of the dams will be covered further in the closure specialist studies.

Impact SWSS 2: Increase in flooding in the pit due to lack of stormwater diversion from the Gbeni operations causing an impact on operations

Currently a river runs through the Gbeni mining pit which increases the risk of flooding in the pit. The impact of the flooding would be minor, localised to the Gbeni operation and short term in nature. The implementation of a formalised natural water diversion drain (Gbeni East Trench), would reduce the localised flooding and allow mining to occur without interruption. The upgrading of the Gbeni West Trench would further assist in abating the flooding in the Gbeni operations.

Table 11-6: Impact SWSS 2 - Increase in flooding in the pit due to lack of stormwater diversion from the Gbeni operations causing an impact on operations

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ / -	Confidence
Before Management	*Minor*	*Short term*	*Site/local*	***Low***	***Definite***	***Medium***	-	*High*
Management Measures: • Formalise and size the river diversion (as per the SWMP) where the Gbeni East Trench is located; and • Ensure the correct sizing of the Gbeni West Trench as per the SWMP.								
After Management	*Minor*	*Short term*	*Site/local*	***Low***	***Possible***	***Low***	-	*High*

Impact SWSS 3: Decrease in water quality downstream of the Gangama and Gbeni operations due to inadequate stormwater management

Due to the lack of an adequate stormwater management system around the Gangama and Gbeni operations, stormwater with high concentrations of sand and sediment leave the operations under low flow conditions. The construction of relevant storm water management infrastructure such as river diversions and silt traps before the stormwater enters the downstream environments is thus crucial to maintaining a high water quality standard. The water flowing from the operations will then have a low impact on the receiving environment.

Table 11-7: Impact SWSS 3 - Decrease in water quality downstream of the Gangama and Gbeni operations due to inadequate stormwater management

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ / -	Confidence
Before Management	*Moderate*	*Long term*	*Site/local*	***Medium***	***Definite***	***Medium***	-	*High*
Management Measures: • Formalise and size the river diversion (as per the SWMP) where the Gbeni East Trench is located; • Ensure the correct sizing of the Gbeni West Trench as per the SWMP; and • Construct silt traps as per the SWMP.								
After Management	*Minor*	*Long term*	*Site/local*	***Medium***	***Unlikely***	***Low***	-	*High*

Impact SWSS 4: Dam walls being overtopped or failing as a result of freeboard requirements not being sufficient and a large flood event occurs

There is a risk that the dams may fail if the freeboard requirements are not adhered to and a large flood event occurs. Due to the height and the amount of water stored behind some of the dam walls, the potential for catastrophic consequences is a reality should a dam wall be overtopped or fail.

Table 11-8: Impact SWSS 4 - Dam walls being overtopped or failing as a result of freeboard requirements not being sufficient and a large flood event occurs

<table>
<tr><th></th><th>Magnitude</th><th>Duration</th><th>Scale</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>+ /-</th><th>Confidence</th></tr>
<tr><td>Before Management</td><td>Major</td><td>Short term</td><td>Regional</td><td>Medium</td><td>Possible</td><td>Medium</td><td>-</td><td>Medium</td></tr>
<tr><td colspan="9">Management Measures:
External measures:
• Investigate if an early warning system could be implemented to ensure that should one of the dam walls be noticed to be of failing integrity or about to be overtopped, the people downstream of that particular dam wall need to be informed so that they can vacate the area of concern.
Internal measures:
• Regular dam safety inspections should be conducted.
• Piezometers have been installed in some of the dam walls and a TSF management plan is in place. The operation confirms to ANCOLD standards and the dams have a operating procedure in place.
• A dam break study should be investigated to identify the zone of influence as a dam wall failing could be catastrophic.
• The water balance should be looked at in greater depth with actual measured values being introduced to greater effect so that confidence can be built into the water balance and the projections made from it. This is currently underway.
• The formal dams should have a 1.8 to 2 m freeboard, while tailings dams should have 0.8 m of freeboard.
• Emergency planning and mitigation measures should be developed and implemented should the water level become too high. These should include:
o Emergency pumps to assist the lowering of the water level in the dams;
o An alternate dam dewatering outlet once a certain threshold limit has been reached to release water into the environment; and
o Protocols surrounding human and machinery not being allowed within certain areas that may be in jeopardy.
Post closure measures:
• The dam walls should either be removed or reduced in their height. This will be covered in more detail in the closure report;
• Once this is done, dam break scenarios for the remaining dam walls should be undertaken;
• Regular dam safety inspections should be conducted and included as part of the rehabilitation plan;
• The water balance should be updated to inform potential overtopping within certain allowable confidence levels; and
• The spillways of the dams would, once again, need to be accurately sized so that the water levels do not build up to the level where the 800 mm of freeboard in these dams is ever compromised.</td></tr>
<tr><td>After Management</td><td>Major</td><td>Short term</td><td>Regional</td><td>Medium</td><td>Unlikely</td><td>Low</td><td>-</td><td>High</td></tr>
</table>

If the abovementioned mitigation and management measures are followed, the significance of the impact becomes low due to the unlikelihood of its occurrence.

Impact SWSS 5: Insufficient water necessary for mining and processing at Lanti and MSP operations

The future mining plan at Lanti operations includes dry mining. With the expansion of dry mining at Lanti there is a possibility of insufficient water due to the higher water demand. The scale of the impact is localized; however the lack of sufficient water has a higher long-term significance to the operational capacity of the mine and the plant.

At the MSP, if ponds are removed while the MSP is still operational, there is a possibility that the water available to run the plant and water used during processing may be insufficient.

Table 11-9: Impact SWSS 5 - Insufficient water necessary for mining and processing at Lanti and MSP operations

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ /-	Confidence
Before Management	*Moderate*	*Long term*	*Site/local*	***Medium***	***Possible***	***Medium***	-	*Medium*
Management Measures: • Update water balance with dam volumes, actual water volumes used in the plant and during mining (long term data); • Provide data on current make-up water requirements; and • If ponds are to be removed from MSP area ensure an alternate water supply to guarantee continuation of mineral processing activities.								
After Management	*Minor*	*Long term*	*Site / local*	***Medium***	***Unlikely***	***Low***	-	*Medium*

Updating the conceptual water balance into a working model allows management to better understand the water demands during mining and processing. It also ensures that forward planning of water demands is possible based on projected mining and processing tonnages. When ponds at the MSP are removed it is important to ensure that there is an alternate water supply to continue with the mining activities.

Impact SWSS 6: Excess water release may affect downstream users from Gangama operation

Water from the Gangama operation has to be released downstream which could have a negative impact on downstream users.

The pH of the water being released from the Gangama operation is between 5.8 and 6.3 based on the samples taken. The majority of the other water quality parameters are well within the required the Sierra Leone standards apart from turbidity and aluminium, which are marginally higher than SANS (there were no Sierra Leone standards to compare these two parameters to).

Table 11-10: Impact SWSS 6 - Excess water release may affect downstream users from Gangama operation

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ /-	Confidence
Before Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Possible***	***Medium***	-	*Medium*
Management Measures: • Monitoring of the water being released to the environment must continue. Should the water quality decrease due to mining, then additional controls will be needed.								
After Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Unlikely***	***Low***	-	*Medium*

Currently the water quality being measured downstream of the Gangama operation does not significantly deteriorate due to the mine. Monitoring of the water being released to the environment must continue. Should the water quality decrease due to mining, then additional controls will be needed.

Impact SWSS 7: Discharge of acidic water from the MSP and Lanti operation leading to reduction in pH and increased acidity resulting in acidic, soft and corrosive water affecting the natural water system

Given that, the natural surface water quality of the area is already slightly acidic and without buffering capacity, the discharge of acidic water from the MSP and Lanti dredge ponds may lead to further reduction in pH and increased acidity in the receiving surface water. The scale of the impact will mainly be localised in the surface waters around the MSP and Lanti dredge ponds within the mine lease area. This may result in acidic, soft and corrosive surface water. Table 11-11 presents a summary of the impact assessment for the potential change in water quality associated with the release of acidic water from the MSP and Lanti pond into the environment.

There is no evidence of heavy metal leaching, however water of pH below 4.0 may cause irritation to the skin and worsen existing skin conditions. Aquatic life also suffers from the effects of low pH and may die at pH levels below 4.5.

Table 11-11: SWSS 7 - Discharge of acidic water from the MSP and Lanti operation leading to reduction in pH and increased acidity resulting in acidic, soft and corrosive water affecting the natural water system

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ /-	Confidence
Before Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Possible***	***Medium***	-	*Medium*
Management Measures: • Controlled release of the water from MSP ponds into Mogbwemo Dredge Pond and into the natural water system.								
After Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Unlikely***	***Low***	-	*Medium*

Controlled release of the water from the acidic ponds into the other less acidic water will help dilute the acidity and its effects.

Impact SWSS 8: Potential use of acidic, soft and corrosive water at Lanti Dry mine process plant resulting in corrosion and damage of metallic structures, equipment and pipes

Water from Lanti dredge pond flows into C3 Dam, through to L4 Dam, CP3A and CP3B Dams and is pumped into the process water tank for use at the Lanti Dry Mining WCP. The pH of the water is therefore an important operational water quality parameter. Acidic, soft and corrosive process water will potentially corrode metals and damage metal pipes at Lanti WCP. Table 11-12 presents a summary of the impact assessment for the potential use of acidic, soft and corrosive process water at Lanti WCP.

Table 11-12: SWSS 8 - Potential use of acidic, soft and corrosive water at Lanti WCP resulting in corrosion and damage of metallic structures, equipment and pipes

	Magnitude	Duration	Scale	Consequence	Probability	Significance	+ /-	Confidence
Before Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Possible***	***Medium***	-	*Medium*
Management Measures: • Liming of the acidic water at the Process Water Tank to neutralize acidity and to buffer the water from rapid pH fluctuations. • Monitoring of the quality of water used as process water.								
After Management	*Moderate*	*Long term*	*Site / local*	***Medium***	***Unlikely***	***Low***	-	*Medium*

Liming of the acidic water at the Process Water Tank will neutralize acidity and buffer the process water from rapid fluctuations in pH before use as process water. Monitoring of the pH of the process water is necessary to ensure that fluctuations are detected promptly and managed to within operational water quality levels.

12 Conclusions and Recommendations

The proposed mining areas and associated infrastructure, are suitably located to have minimal impact on the surface water resources as long as the mitigation and management measures are implemented. The impacts before and after the mitigation and management measures have been implemented are presented in Section 11. These mitigation and management measures should be implemented in order to protect the water resources in and around the mining area.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendices

Appendix A: WRSM catchment modelling results

Table A1: S1,S11 & S12A catchments: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.58	0.53	0.47	0.41	0.37	0.37	0.84	1.9	3.13	0.53	0.55	0.59	10.27	0.86
2002	3.68	2.97	2.36	1.86	1.46	1.17	1.11	1.96	3.82	4.72	5.32	4.51	34.95	2.91
2003	3.35	2.71	2.14	1.69	1.4	1.59	2.55	6.82	12.68	4.76	4.43	3.91	48.04	4
2004	5.41	4.03	3.01	2.24	1.77	1.66	2.45	3.6	4.85	12.96	9.67	7.21	58.87	4.91
2005	3.85	3.08	2.44	1.96	1.57	1.38	1.83	4.45	6.84	5.79	5.57	4.71	43.45	3.62
2006	4.3	3.24	2.47	1.89	1.5	1.7	2.82	4.86	6.59	8.66	7.4	5.53	50.95	4.25
2007	3.85	3.02	2.35	1.83	1.39	1.22	3.48	9.15	14.96	7.25	6.19	4.72	59.4	4.95
2008	6.45	4.58	3.37	2.52	2	1.97	2.99	4.63	7.51	15.55	12.15	8.75	72.46	6.04
2009	5.15	3.83	2.92	2.2	1.67	1.39	1.86	4.25	3.39	9.78	8.97	6.61	52.03	4.34
2010	2.7	2.24	1.84	1.51	1.32	1.48	2.96	5.43	9.26	3.97	3.66	3.11	39.48	3.29
2011	5.57	4.1	3.11	2.35	1.83	2	2.23	3.97	4.35	11.28	9.88	7.23	57.88	4.82
2012	3.07	2.55	2.07	1.66	1.38	1.22	2.66	6.66	10.39	4.24	4.23	3.54	43.69	3.64
2013	5.13	3.77	2.85	2.15	1.7	1.95	3.49	4.46	6.04	11.43	9.18	6.77	58.92	4.91
2014	4.18	3.25	2.51	1.93	1.57	1.97	3.81	7.98	13.91	7.35	6.84	5.22	60.5	5.04
2015	5.75	4.14	3.08	2.31	1.78	2.16	3.08	4.92	9.45	13.89	10.55	7.6	68.73	5.73
2016	5.66	4.11	3.08	2.29	1.74	1.39	3.93	7.46	12.54	12.07	10.19	7.43	71.88	5.99
AVERAGE	8.39	7.17	5.47	4.29	3.26	2.5	1.92	1.53	1.54	2.63	5.16	8.11	51.97	4.33
PERCENTILE														
0.1	3.182	2.709	2.295	1.842	1.488	1.383	1.38	1.39	1.391	4.105	3.996	3.624		
0.3	4.417	3.892	3.175	2.752	2.292	1.969	1.97	2.035	2.209	5.275	5.395	4.724		
0.5	5.57	4.74	4.235	3.88	3.36	3.075	3	3.08	3.38	8.005	7.375	6.805		
0.7	7.355	6.791	5.77	5.494	5.093	4.593	4.233	4.545	4.857	11.355	9.85	8.741		
0.9	11.061	10.226	9.83	9.621	9.033	8.723	7.706	7.79	9.177	13.425	12.142	11.622		
0.98	13.6482	13.3506	13.053	12.7818	12.5226	12.2634	12.1356	12.11	13.1274	15.052	14.5208	13.9896		

Table A2: S2_S5 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.04	0.07	0.04	0.04	0.04	0.47	0.04
2002	0.21	0.18	0.15	0.12	0.1	0.08	0.07	0.08	0.14	0.17	0.25	0.23	1.77	0.15
2003	0.19	0.16	0.14	0.11	0.09	0.08	0.09	0.32	0.84	0.2	0.21	0.21	2.64	0.22
2004	0.45	0.31	0.23	0.16	0.19	0.18	0.28	0.36	0.4	1.1	0.82	0.61	5.10	0.43
2005	0.3	0.22	0.17	0.16	0.11	0.19	0.28	0.41	0.55	0.52	0.5	0.34	3.75	0.31
2006	0.35	0.23	0.17	0.14	0.14	0.24	0.27	0.43	0.5	0.73	0.6	0.44	4.23	0.35
2007	0.3	0.21	0.15	0.13	0.1	0.15	0.44	0.86	1.38	0.58	0.5	0.34	5.13	0.43
2008	0.57	0.39	0.26	0.2	0.22	0.21	0.31	0.41	0.63	1.42	1.08	0.76	6.45	0.54
2009	0.42	0.28	0.2	0.15	0.12	0.2	0.22	0.43	0.15	0.84	0.77	0.52	4.30	0.36
2010	0.18	0.14	0.12	0.1	0.14	0.17	0.28	0.48	0.8	0.3	0.25	0.19	3.16	0.26
2011	0.46	0.31	0.23	0.17	0.17	0.27	0.2	0.38	0.31	1	0.87	0.58	4.93	0.41
2012	0.23	0.16	0.13	0.11	0.12	0.13	0.33	0.62	0.9	0.27	0.3	0.21	3.53	0.29
2013	0.43	0.28	0.2	0.15	0.19	0.24	0.35	0.35	0.47	1	0.78	0.57	5.02	0.42
2014	0.33	0.23	0.16	0.13	0.17	0.25	0.37	0.73	1.3	0.6	0.57	0.39	5.23	0.44
2015	0.49	0.33	0.21	0.18	0.17	0.28	0.3	0.43	0.84	1.24	0.94	0.64	6.06	0.51
2016	0.48	0.31	0.21	0.16	0.16	0.16	0.47	0.67	1.15	1.07	0.89	0.61	6.35	0.53
AVERAGE	0.69	0.59	0.42	0.34	0.24	0.17	0.14	0.14	0.18	0.27	0.44	0.65	4.26	0.35
PERCENTILE														
0.1	0.19	0.169	0.145	0.121	0.11	0.103	0.1	0.1	0.1	0.185	0.201	0.20		
0.3	0.3	0.244	0.21	0.18	0.17	0.16	0.17	0.17	0.17	0.41	0.36	0.30		
0.5	0.47	0.345	0.3	0.25	0.22	0.21	0.22	0.23	0.25	0.665	0.6	0.57		
0.7	0.601	0.57	0.5	0.447	0.386	0.33	0.33	0.365	0.417	1	0.861	0.76		
0.9	0.982	0.895	0.855	0.816	0.773	0.751	0.649	0.7	0.798	1.17	1.079	1.02		
0.98	1.2036	1.1588	1.114	1.0956	1.0892	1.0828	1.0782	1.075	1.1662	1.366	1.3084	1.25		

Table A3: S6 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.23	0.02
2002	0.1	0.09	0.07	0.06	0.05	0.04	0.04	0.04	0.07	0.09	0.13	0.12	0.89	0.07
2003	0.09	0.08	0.07	0.05	0.04	0.04	0.04	0.16	0.36	0.1	0.11	0.10	1.26	0.11
2004	0.17	0.13	0.1	0.08	0.06	0.05	0.05	0.06	0.1	0.39	0.3	0.23	1.72	0.14
2005	0.12	0.1	0.08	0.06	0.05	0.04	0.04	0.05	0.13	0.15	0.15	0.13	1.10	0.09
2006	0.13	0.1	0.08	0.06	0.05	0.04	0.04	0.05	0.12	0.21	0.2	0.16	1.26	0.1
2007	0.12	0.1	0.08	0.06	0.05	0.04	0.04	0.16	0.37	0.17	0.15	0.13	1.46	0.12
2008	0.2	0.15	0.11	0.08	0.07	0.05	0.05	0.05	0.14	0.42	0.34	0.26	1.93	0.16
2009	0.15	0.12	0.09	0.07	0.06	0.05	0.04	0.05	0.06	0.24	0.23	0.19	1.34	0.11
2010	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.07	0.19	0.07	0.08	0.08	0.87	0.07
2011	0.16	0.13	0.1	0.08	0.06	0.05	0.05	0.05	0.06	0.29	0.26	0.21	1.49	0.12
2012	0.09	0.08	0.07	0.05	0.05	0.04	0.04	0.1	0.23	0.08	0.09	0.09	1.00	0.08
2013	0.16	0.12	0.09	0.07	0.06	0.05	0.05	0.06	0.11	0.29	0.25	0.20	1.50	0.13
2014	0.12	0.1	0.08	0.06	0.05	0.04	0.05	0.14	0.33	0.17	0.17	0.15	1.48	0.12
2015	0.18	0.14	0.1	0.08	0.06	0.05	0.05	0.06	0.19	0.38	0.29	0.23	1.80	0.15
2016	0.17	0.13	0.1	0.08	0.06	0.05	0.04	0.12	0.29	0.31	0.27	0.22	1.84	0.15
AVERAGE	0.21	0.19	0.16	0.13	0.1	0.08	0.06	0.05	0.04	0.04	0.08	0.17	1.32	0.11
PERCENTILE														
0.1	0.08	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.075	0.08	0.08		
0.3	0.12	0.1	0.09	0.08	0.071	0.06	0.05	0.05	0.05	0.125	0.136	0.13		
0.5	0.16	0.135	0.12	0.1	0.1	0.09	0.08	0.08	0.08	0.19	0.185	0.17		
0.7	0.21	0.183	0.17	0.15	0.149	0.13	0.12	0.12	0.13	0.29	0.267	0.23		
0.9	0.29	0.29	0.265	0.259	0.243	0.23	0.23	0.215	0.23	0.385	0.337	0.30		
0.98	0.3874	0.3842	0.381	0.3712	0.3584	0.3456	0.3346	0.325	0.3618	0.411	0.4014	0.39		

Table A4: S7 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.03	0.03	0.03	0.33	0.03
2002	0.15	0.13	0.1	0.08	0.07	0.06	0.05	0.05	0.1	0.12	0.18	0.16	1.24	0.1
2003	0.13	0.12	0.1	0.08	0.06	0.06	0.06	0.23	0.51	0.14	0.15	0.15	1.77	0.15
2004	0.24	0.19	0.14	0.11	0.08	0.07	0.07	0.08	0.14	0.55	0.42	0.32	2.41	0.2
2005	0.16	0.14	0.11	0.09	0.07	0.06	0.06	0.07	0.18	0.2	0.21	0.19	1.54	0.13
2006	0.18	0.15	0.11	0.09	0.07	0.06	0.06	0.08	0.17	0.29	0.28	0.23	1.77	0.15
2007	0.16	0.13	0.11	0.09	0.07	0.05	0.06	0.23	0.51	0.24	0.21	0.19	2.05	0.17
2008	0.28	0.21	0.16	0.12	0.09	0.07	0.07	0.08	0.2	0.59	0.48	0.37	2.7	0.23
2009	0.21	0.17	0.13	0.1	0.08	0.06	0.06	0.06	0.08	0.33	0.32	0.26	1.88	0.16
2010	0.11	0.1	0.08	0.07	0.06	0.06	0.06	0.1	0.27	0.1	0.11	0.12	1.23	0.1
2011	0.23	0.18	0.14	0.11	0.09	0.07	0.07	0.07	0.09	0.4	0.36	0.29	2.1	0.17
2012	0.12	0.11	0.09	0.08	0.06	0.06	0.06	0.14	0.32	0.11	0.13	0.13	1.41	0.12
2013	0.22	0.17	0.13	0.1	0.08	0.07	0.07	0.08	0.15	0.41	0.35	0.28	2.11	0.18
2014	0.18	0.14	0.12	0.09	0.07	0.06	0.07	0.2	0.47	0.24	0.24	0.21	2.07	0.17
2015	0.25	0.19	0.14	0.11	0.08	0.07	0.07	0.08	0.27	0.53	0.41	0.32	2.52	0.21
2016	0.24	0.19	0.14	0.11	0.08	0.06	0.06	0.17	0.41	0.43	0.38	0.3	2.59	0.22
AVERAGE	0.29	0.27	0.22	0.18	0.15	0.12	0.09	0.07	0.06	0.06	0.11	0.25	1.86	0.15
PERCENTILE														
0.1	0.11	0.11	0.1	0.081	0.07	0.06	0.06	0.06	0.06	0.105	0.11	0.11		
0.3	0.16	0.15	0.13	0.113	0.101	0.09	0.07	0.07	0.08	0.17	0.186	0.181		
0.5	0.225	0.19	0.175	0.15	0.14	0.125	0.11	0.11	0.11	0.265	0.26	0.24		
0.7	0.29	0.253	0.24	0.21	0.199	0.19	0.173	0.17	0.18	0.405	0.374	0.32		
0.9	0.41	0.401	0.375	0.359	0.336	0.32	0.32	0.295	0.32	0.54	0.475	0.423		
0.98	0.5448	0.5384	0.532	0.519	0.503	0.487	0.471	0.455	0.51	0.578	0.5652	0.5524		

Table A5: S8: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.15	0.12	0.11	0.09	0.09	0.11	0.43	0.88	1.12	0.17	0.19	0.18	3.63	0.3
2002	0.66	0.55	0.46	0.37	0.3	0.26	0.28	1.03	1.43	1.18	0.98	0.77	8.26	0.69
2003	0.6	0.51	0.42	0.33	0.3	0.47	0.99	2.32	3.33	0.96	0.75	0.69	11.67	0.97
2004	1.07	0.81	0.62	0.46	0.39	0.38	1	1.21	1.11	2.72	1.89	1.42	13.08	1.09
2005	0.72	0.6	0.49	0.41	0.33	0.32	0.63	1.3	1.58	1.17	1.05	0.87	9.47	0.79
2006	0.81	0.64	0.5	0.39	0.33	0.36	0.76	1.41	1.44	1.67	1.34	1.02	10.66	0.89
2007	0.72	0.58	0.47	0.38	0.29	0.3	1.29	2.54	3.34	1.28	1.05	0.87	13.11	1.09
2008	1.21	0.91	0.69	0.53	0.43	0.39	0.75	1.32	1.77	3.04	2.23	1.61	14.86	1.24
2009	0.94	0.74	0.57	0.44	0.35	0.35	0.48	1.48	0.74	1.94	1.59	1.20	10.82	0.9
2010	0.49	0.42	0.37	0.32	0.32	0.34	0.79	2.43	3.07	0.87	0.67	0.55	10.65	0.89
2011	1.02	0.79	0.62	0.48	0.4	0.42	0.5	1.55	1.53	2.78	2.15	1.31	13.54	1.13
2012	0.56	0.48	0.41	0.34	0.33	0.32	0.89	2.91	3.25	0.85	0.82	0.62	11.79	0.98
2013	0.96	0.74	0.57	0.44	0.4	0.41	1.14	1.94	1.9	2.71	1.77	1.24	14.23	1.19
2014	0.77	0.62	0.49	0.39	0.4	0.52	1.27	3.46	4.44	1.8	1.43	0.95	16.54	1.38
2015	1.07	0.81	0.62	0.48	0.41	0.49	0.89	2.45	3.37	3.06	2.15	1.40	17.21	1.43
2016	1.04	0.8	0.61	0.46	0.39	0.35	1.41	3.44	4.01	3.02	2.13	1.35	18.99	1.58
AVERAGE	1.83	1.39	1	0.8	0.63	0.5	0.39	0.34	0.36	0.84	1.98	2.34	12.41	1.03

PERCENTILE												
0.1	0.572	0.508	0.44	0.371	0.327	0.32	0.32	0.32	0.33	0.86	0.757	0.66
0.3	0.847	0.74	0.62	0.536	0.46	0.41	0.427	0.46	0.48	1.175	1.05	0.95
0.5	1.05	0.945	0.81	0.74	0.63	0.59	0.62	0.68	0.75	1.735	1.51	1.26
0.7	1.402	1.252	1.12	1.034	0.959	0.87	0.896	1.025	1.177	2.715	2.073	1.66
0.9	2.206	2.15	2.035	1.881	1.779	1.652	1.592	1.94	2.311	3.03	2.774	2.71
0.98	3.0348	3.0284	3.022	2.9672	2.8904	2.8136	2.7692	3.03	3.3826	3.054	3.0476	3.04

Table A6: S9 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.12	0.01
2002	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.04	0.05	0.07	0.06	0.47	0.04
2003	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.09	0.19	0.05	0.06	0.06	0.67	0.06
2004	0.09	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.05	0.21	0.16	0.12	0.91	0.08
2005	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.03	0.07	0.08	0.08	0.07	0.59	0.05
2006	0.07	0.06	0.04	0.03	0.03	0.02	0.02	0.03	0.07	0.11	0.11	0.09	0.67	0.06
2007	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.09	0.19	0.09	0.08	0.07	0.78	0.06
2008	0.1	0.08	0.06	0.05	0.03	0.03	0.03	0.03	0.07	0.22	0.18	0.14	1.03	0.09
2009	0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.13	0.12	0.1	0.71	0.06
2010	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.04	0.1	0.04	0.04	0.04	0.47	0.04
2011	0.09	0.07	0.05	0.04	0.03	0.03	0.02	0.03	0.03	0.15	0.14	0.11	0.8	0.07
2012	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.05	0.12	0.04	0.05	0.05	0.53	0.04
2013	0.08	0.07	0.05	0.04	0.03	0.03	0.02	0.03	0.06	0.16	0.13	0.11	0.8	0.07
2014	0.07	0.05	0.04	0.03	0.03	0.02	0.03	0.07	0.18	0.09	0.09	0.08	0.79	0.07
2015	0.09	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.1	0.2	0.15	0.12	0.96	0.08
2016	0.09	0.07	0.05	0.04	0.03	0.02	0.02	0.07	0.16	0.16	0.15	0.11	0.98	0.08
AVERAGE	0.07	0.06	0.04	0.03	0.03	0.02	0.02	0.04	0.09	0.11	0.1	0.08	0.7	0.06
PERCENTILE														
0.1	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.04		
0.3	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.065	0.073	0.07		
0.5	0.085	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.1	0.1	0.09		
0.7	0.11	0.093	0.09	0.08	0.079	0.07	0.07	0.065	0.07	0.155	0.147	0.12		
0.9	0.157	0.15	0.145	0.139	0.13	0.12	0.12	0.11	0.12	0.205	0.178	0.16		
0.98	0.2074	0.2042	0.201	0.1956	0.1892	0.1828	0.1764	0.17	0.19	0.217	0.2138	0.2106		

Table A7: S10 & S12B catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
2001	0.01	0.01	0.01	0.01	0.03	0.04	0.05	0.07	0.07	0.01	0.02	0.01	0.34	0.03
2002	0.05	0.04	0.04	0.24	0.27	0.39	0.41	0.73	0.92	0.08	0.08	0.05	3.31	0.28
2003	0.63	0.47	0.33	0.32	0.45	0.57	0.7	1.84	3.22	0.83	0.86	0.67	10.89	0.91
2004	1.26	0.87	0.64	0.45	0.57	0.53	0.74	0.78	0.93	3.11	2.27	1.68	13.83	1.15
2005	0.79	0.62	0.47	0.47	0.31	0.48	0.66	1.37	1.67	1.24	1.21	0.91	10.2	0.85
2006	0.95	0.65	0.47	0.39	0.41	0.65	0.88	1.44	1.5	2.13	1.66	1.18	12.29	1.02
2007	0.8	0.58	0.41	0.39	0.21	0.52	1.36	2.69	4.05	1.67	1.42	0.92	15	1.25
2008	1.57	1.04	0.72	0.57	0.58	0.63	1.19	1.67	2.23	4.24	3.3	2.23	19.96	1.66
2009	1.14	0.77	0.56	0.42	0.35	0.54	0.64	1.63	0.4	2.78	2.44	1.41	13.08	1.09
2010	0.5	0.37	0.34	0.33	0.43	0.42	0.89	1.72	2.8	0.92	0.72	0.52	9.95	0.83
2011	1.26	0.85	0.64	0.47	0.48	0.74	0.63	1.48	1.06	3.26	2.77	1.62	15.25	1.27
2012	0.62	0.44	0.32	0.31	0.42	0.38	0.96	2.28	3.08	0.83	0.93	0.6	11.17	0.93
2013	1.18	0.79	0.57	0.43	0.51	0.69	1.32	1.31	1.61	3.26	2.37	1.6	15.63	1.3
2014	0.89	0.63	0.43	0.37	0.54	0.69	1.33	2.78	4.48	1.98	1.76	1.06	16.96	1.41
2015	1.35	0.9	0.6	0.51	0.49	0.81	1.12	1.76	2.99	3.93	2.94	1.81	19.2	1.6
2016	1.31	0.86	0.59	0.43	0.46	0.43	1.71	2.61	3.96	3.52	2.8	1.74	20.39	1.7
AVERAGE	0.89	0.62	0.45	0.38	0.41	0.53	0.91	1.63	2.19	2.11	1.72	1.13	12.97	1.08
PERCENTILE														
0.1	0.08	0.077	0.065	0.08	0.08	0.119	0.197	0.225	0.243	0.455	0.144	0.08		
0.3	0.857	0.755	0.6	0.47	0.45	0.449	0.467	0.47	0.483	1.08	1.014	0.92		
0.5	1.25	0.94	0.86	0.745	0.625	0.61	0.635	0.68	0.735	2.055	1.87	1.61		
0.7	1.742	1.606	1.33	1.201	1.031	0.911	0.923	1.18	1.295	3.185	2.777	2.22		
0.9	3.059	2.814	2.775	2.433	2.3	2.2	1.995	2.25	2.682	3.725	3.296	3.26		
0.98	3.8234	3.6922	3.561	3.4716	3.4012	3.3308	3.2928	3.28	3.9354	4.147	4.0478	3.95		

Table A8: S12 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL	Average
2001	0.07	0.07	0.06	0.05	0.04	0.04	0.05	0.08	0.13	0.07	0.07	0.07	0.81	0.07
2002	0.36	0.31	0.26	0.21	0.17	0.14	0.12	0.13	0.24	0.3	0.43	0.41	3.08	0.26
2003	0.33	0.29	0.24	0.19	0.16	0.14	0.16	0.56	1.26	0.35	0.37	0.36	4.39	0.37
2004	0.6	0.46	0.35	0.26	0.2	0.17	0.17	0.2	0.35	1.37	1.04	0.79	5.96	0.5
2005	0.4	0.34	0.27	0.22	0.18	0.16	0.15	0.18	0.43	0.5	0.51	0.46	3.81	0.32
2006	0.46	0.36	0.28	0.22	0.17	0.15	0.15	0.19	0.43	0.71	0.69	0.57	4.37	0.36
2007	0.4	0.33	0.27	0.21	0.17	0.14	0.14	0.56	1.27	0.59	0.53	0.47	5.07	0.42
2008	0.68	0.52	0.39	0.29	0.23	0.18	0.17	0.19	0.49	1.45	1.19	0.90	6.68	0.56
2009	0.53	0.42	0.33	0.25	0.2	0.16	0.14	0.16	0.2	0.82	0.79	0.65	4.64	0.39
2010	0.27	0.24	0.2	0.17	0.15	0.14	0.15	0.24	0.67	0.25	0.27	0.28	3.03	0.25
2011	0.57	0.45	0.35	0.27	0.21	0.17	0.16	0.18	0.22	0.99	0.89	0.72	5.18	0.43
2012	0.31	0.27	0.23	0.19	0.16	0.14	0.14	0.34	0.8	0.27	0.31	0.32	3.48	0.29
2013	0.54	0.42	0.33	0.25	0.19	0.16	0.16	0.2	0.38	1.01	0.87	0.69	5.22	0.43
2014	0.43	0.36	0.29	0.22	0.18	0.16	0.17	0.49	1.15	0.59	0.59	0.51	5.12	0.43
2015	0.61	0.47	0.36	0.27	0.21	0.17	0.16	0.2	0.67	1.32	1.01	0.78	6.23	0.52
2016	0.59	0.46	0.35	0.27	0.2	0.16	0.15	0.43	1.01	1.07	0.95	0.75	6.40	0.53
AVERAGE	0.73	0.66	0.55	0.45	0.36	0.28	0.22	0.18	0.15	0.15	0.27	0.61	4.59	0.38
PERCENTILE														
0.1	0.27	0.27	0.245	0.21	0.17	0.15	0.14	0.14	0.14	0.26	0.27	0.27		
0.3	0.4	0.36	0.33	0.28	0.26	0.21	0.18	0.18	0.19	0.425	0.451	0.43		
0.5	0.555	0.47	0.425	0.36	0.345	0.31	0.27	0.27	0.275	0.65	0.64	0.59		
0.7	0.711	0.622	0.59	0.53	0.497	0.46	0.423	0.42	0.43	1	0.932	0.79		
0.9	1.01	0.992	0.925	0.888	0.835	0.79	0.781	0.735	0.79	1.345	1.178	1.05		
0.98	1.357	1.341	1.325	1.2914	1.2498	1.2082	1.1684	1.13	1.2618	1.426	1.4004	1.37		

Table A9: S13 catchment: WRSM2000 mean annual runoff (MAR) (MCM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL	Average
2001	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.19	0.02
2002	0.08	0.07	0.06	0.05	0.04	0.03	0.03	0.03	0.06	0.07	0.1	0.09	0.72	0.06
2003	0.08	0.07	0.05	0.04	0.04	0.03	0.04	0.13	0.29	0.08	0.09	0.08	1.02	0.08
2004	0.14	0.11	0.08	0.06	0.05	0.04	0.04	0.05	0.08	0.32	0.24	0.18	1.39	0.12
2005	0.09	0.08	0.06	0.05	0.04	0.04	0.03	0.04	0.1	0.12	0.12	0.11	0.89	0.07
2006	0.11	0.08	0.07	0.05	0.04	0.03	0.03	0.04	0.1	0.17	0.16	0.13	1.02	0.08
2007	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.13	0.29	0.14	0.12	0.11	1.18	0.1
2008	0.16	0.12	0.09	0.07	0.05	0.04	0.04	0.04	0.11	0.34	0.28	0.21	1.55	0.13
2009	0.12	0.1	0.08	0.06	0.05	0.04	0.03	0.04	0.05	0.19	0.18	0.15	1.08	0.09
2010	0.06	0.06	0.05	0.04	0.03	0.03	0.03	0.06	0.16	0.06	0.06	0.07	0.70	0.06
2011	0.13	0.1	0.08	0.06	0.05	0.04	0.04	0.04	0.05	0.23	0.21	0.17	1.21	0.1
2012	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.08	0.19	0.06	0.07	0.07	0.81	0.07
2013	0.13	0.1	0.08	0.06	0.05	0.04	0.04	0.05	0.09	0.24	0.2	0.16	1.21	0.1
2014	0.1	0.08	0.07	0.05	0.04	0.04	0.04	0.11	0.27	0.14	0.14	0.12	1.19	0.1
2015	0.14	0.11	0.08	0.06	0.05	0.04	0.04	0.05	0.16	0.31	0.23	0.18	1.45	0.12
2016	0.14	0.11	0.08	0.06	0.05	0.04	0.04	0.1	0.24	0.25	0.22	0.17	1.49	0.12
AVERAGE	0.17	0.15	0.13	0.1	0.08	0.07	0.05	0.04	0.03	0.03	0.06	0.14	1.07	0.09
PERCENTILE														
0.1	0.06	0.06	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.06	0.06	0.06		
0.3	0.09	0.08	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.1	0.106	0.10		
0.5	0.13	0.11	0.1	0.08	0.08	0.07	0.06	0.06	0.065	0.155	0.15	0.14		
0.7	0.17	0.143	0.14	0.12	0.119	0.11	0.1	0.1	0.1	0.235	0.217	0.18		
0.9	0.237	0.23	0.215	0.209	0.193	0.18	0.18	0.17	0.18	0.315	0.277	0.24		
0.98	0.3174	0.3142	0.311	0.3034	0.2938	0.2842	0.2746	0.265	0.29	0.334	0.3276	0.32		

Appendix B: HEC-RAS results

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8E	R1	2165.292	50yrs	327.56	6	6.82	1.23	265.41	370.47
S8E	R1	2165.292	100yrs	442.43	6	7.1	1.19	372.91	397.48
S8E	R1	2090.375	50yrs	327.56	5.02	6.67	1.36	249.42	177.11
S8E	R1	2090.375	100yrs	442.43	5.02	6.93	1.55	296.99	181.33
S8E	R1	2040.875	50yrs	327.56	5	6.54	1.63	203.23	150.37
S8E	R1	2040.875	100yrs	442.43	5	6.78	1.86	240.39	155.29
S8E	R1	1984.989	50yrs	327.56	5	6.43	1.56	210.74	166.84
S8E	R1	1984.989	100yrs	442.43	5	6.66	1.78	253.47	193.7
S8E	R1	1862.572	50yrs	327.56	4.72	5.83	2.35	141.17	155.29
S8E	R1	1862.572	100yrs	442.43	4.72	6.05	2.56	180.11	247.71
S8E	R1	1803.052	50yrs	327.56	4.1	5.72	1.57	221.73	202.37
S8E	R1	1803.052	100yrs	442.43	4.1	5.97	1.72	272.39	208.73
S8E	R1	1681.811	50yrs	327.56	4	5.45	1.62	207.62	162.16
S8E	R1	1681.811	100yrs	442.43	4	5.67	1.87	243.27	164.88
S8E	R1	1616.978	50yrs	327.56	4	5.25	1.82	182.02	159.17
S8E	R1	1616.978	100yrs	442.43	4	5.42	2.13	210.36	160.03

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8E	R1	1559.484	50yrs	327.56	4	5.11	1.58	217.55	250.08
S8E	R1	1559.484	100yrs	442.43	4	5.3	1.78	265.21	265.15
S8E	R1	1497.105	50yrs	327.56	4	4.96	1.46	239.7	277.83
S8E	R1	1497.105	100yrs	442.43	4	5.14	1.7	297.32	341.48
S8E	R1	1438.88	50yrs	327.56	3.86	4.83	1.28	263.89	283.92
S8E	R1	1438.88	100yrs	442.43	3.86	5	1.47	311.38	290.41
S8E	R1	1377.962	50yrs	327.56	3.7	4.61	1.6	214.48	290.61
S8E	R1	1377.962	100yrs	442.43	3.7	4.76	1.78	259.1	292.32
S8E	R1	1331.911	50yrs	327.56	3.49	4.41	1.69	212.19	296.57
S8E	R1	1331.911	100yrs	442.43	3.49	4.58	1.82	263.73	298.56
S8E	R1	1244.131	50yrs	327.56	3.3	4.27	1.01	324.7	336.56
S8E	R1	1244.131	100yrs	442.43	3.3	4.45	1.15	385.46	339.05
S8E	R1	1113.112	50yrs	327.56	2.98	3.86	1.57	208.23	373.74
S8E	R1	1113.112	100yrs	442.43	2.98	4.07	1.43	310.4	645.84
S8E	R1	1070.809	50yrs	327.56	2.97	3.88	0.61	534.8	585.39
S8E	R1	1070.809	100yrs	442.43	2.97	4.08	0.68	648.5	585.82

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8E	R1	1007.646	50yrs	327.56	2.96	3.84	0.71	458.79	527.01
S8E	R1	1007.646	100yrs	442.43	2.96	4.03	0.79	561.75	529.04
S8E	R1	905.9559	50yrs	327.56	2.84	3.74	0.83	396.37	454.24
S8E	R1	905.9559	100yrs	442.43	2.84	3.94	0.91	487.51	460.66
S8E	R1	826.8472	50yrs	327.56	2.45	3.72	0.56	587.3	464.33
S8E	R1	826.8472	100yrs	442.43	2.45	3.91	0.65	679.34	464.42
S8E	R1	692.8109	50yrs	327.56	2.1	3.64	0.8	407.37	377.11
S8E	R1	692.8109	100yrs	442.43	2.1	3.83	0.92	478.74	389.68
S8E	R1	594.343	50yrs	327.56	2	3.58	0.74	444.16	393.29
S8E	R1	594.343	100yrs	442.43	2	3.76	0.86	515.24	404.12
S8E	R1	535.5569	50yrs	327.56	2	3.53	0.86	379.37	372.74
S8E	R1	535.5569	100yrs	442.43	2	3.7	1	443.6	387.3
S8E	R1	459.0497	50yrs	327.56	1.97	3.45	0.91	361.72	357.86
S8E	R1	459.0497	100yrs	442.43	1.97	3.61	1.06	418.3	377.97
S8E	R1	397.6938	50yrs	327.56	1.87	3.41	0.76	431.7	410.38
S8E	R1	397.6938	100yrs	442.43	1.87	3.56	0.9	492.17	419.02

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8E	R1	305.051	50yrs	327.56	1.85	3.35	0.74	444.23	521.85
S8E	R1	305.051	100yrs	442.43	1.85	3.48	0.86	515.51	539.48
S8E	R1	207.9965	50yrs	327.56	1.83	3.26	0.83	411.21	456.3
S8E	R1	207.9965	100yrs	442.43	1.83	3.37	0.99	462.64	477.59
S8E	R1	89.06143	50yrs	327.56	1.81	3.09	1.1	301.54	370.18
S8E	R1	89.06143	100yrs	442.43	1.81	3.09	1.49	301.54	370.18
S8C	R1	3842.95	50yrs	39.54	22	22.55	2.08	19.04	40.66
S8C	R1	3842.95	100yrs	52.93	22	22.64	2.3	23.01	42.89
S8C	R1	3761.105	50yrs	39.54	21	21.25	1.56	25.37	103.47
S8C	R1	3761.105	100yrs	52.93	21	21.29	1.78	29.74	104.01
S8C	R1	3707.506	50yrs	39.54	20.12	20.83	1.09	36.28	79.49
S8C	R1	3707.506	100yrs	52.93	20.12	20.93	1.19	44.52	87.04
S8C	R1	3662.816	50yrs	39.54	20	20.68	0.97	40.58	90.75
S8C	R1	3662.816	100yrs	52.93	20	20.77	1.07	49.69	100.19
S8C	R1	3599.99	50yrs	39.54	20	20.51	0.83	47.66	97.74
S8C	R1	3599.99	100yrs	52.93	20	20.6	0.95	55.99	99.56

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	3543.483	50yrs	39.54	19.82	20.27	1.19	33.16	96.98
S8C	R1	3543.483	100yrs	52.93	19.82	20.35	1.27	41.75	98.92
S8C	R1	3466.896	50yrs	39.54	19	19.45	1.65	23.92	68.56
S8C	R1	3466.896	100yrs	52.93	19	19.5	1.94	27.28	71.6
S8C	R1	3403.682	50yrs	39.54	18.65	19.08	1.02	38.76	92.16
S8C	R1	3403.682	100yrs	52.93	18.65	19.21	1.05	50.6	93.67
S8C	R1	3335.521	50yrs	39.54	18.25	19.01	0.6	66.19	92.83
S8C	R1	3335.521	100yrs	52.93	18.25	19.14	0.67	78.51	94.96
S8C	R1	3204.838	50yrs	39.54	18	18.71	1.44	27.39	52.68
S8C	R1	3204.838	100yrs	52.93	18	18.8	1.65	32.01	55.92
S8C	R1	3139.092	50yrs	39.54	17.85	18.04	1.37	28.95	152.28
S8C	R1	3139.092	100yrs	52.93	17.85	18.08	1.51	35.12	153.02
S8C	R1	3093.662	50yrs	39.54	17	17.74	0.63	62.76	131.55
S8C	R1	3093.662	100yrs	52.93	17	17.86	0.66	79.75	139.3
S8C	R1	3018.964	50yrs	39.54	17	17.61	0.84	46.89	81.75
S8C	R1	3018.964	100yrs	52.93	17	17.74	0.91	57.94	83.73

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	2924.744	50yrs	39.54	16.56	17.44	0.85	46.67	73.84
S8C	R1	2924.744	100yrs	52.93	16.56	17.59	0.92	57.59	77.7
S8C	R1	2845.694	50yrs	39.54	16	17.38	0.67	58.94	58.96
S8C	R1	2845.694	100yrs	52.93	16	17.52	0.79	67	60.55
S8C	R1	2779.762	50yrs	39.54	15.8	17.09	1.98	20.01	51.4
S8C	R1	2779.762	100yrs	52.93	15.8	17.18	2.14	24.73	53.93
S8C	R1	2746.051	50yrs	39.54	15.3	16.31	2.4	16.45	39.33
S8C	R1	2746.051	100yrs	52.93	15.3	16.4	2.65	19.97	41.29
S8C	R1	2545.449	50yrs	39.54	13	14.13	0.29	134.44	189.82
S8C	R1	2545.449	100yrs	52.93	13	14.21	0.36	148.43	191.18
S8C	R1	2433.322	50yrs	39.54	12.6	14.13	0.17	236.75	191.24
S8C	R1	2433.322	100yrs	52.93	12.6	14.2	0.21	250.49	192.14
S8C	R1	2389.403	50yrs	39.54	12.29	14.13	0.16	246.3	196.27
S8C	R1	2389.403	100yrs	52.93	12.29	14.2	0.2	260.31	197.44
S8C	R1	2323.996	50yrs	39.54	11.56	14.13	0.09	418.81	204.34
S8C	R1	2323.996	100yrs	52.93	11.56	14.2	0.12	433.41	205.83

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	2272.315		Culvert					
S8C	R1	2228.319	50yrs	39.54	11.42	12.36	0.3	130.12	146.57
S8C	R1	2228.319	100yrs	52.93	11.42	12.44	0.37	142.57	148.45
S8C	R1	2126.166	50yrs	39.54	11	12.34	0.35	113.23	134.74
S8C	R1	2126.166	100yrs	52.93	11	12.42	0.43	123.85	138.45
S8C	R1	2065.669	50yrs	39.54	11	12.33	0.26	152.19	223.26
S8C	R1	2065.669	100yrs	52.93	11	12.41	0.31	169.41	229.75
S8C	R1	1970.561	50yrs	39.54	10.56	12.33	0.16	250.6	174.87
S8C	R1	1970.561	100yrs	52.93	10.56	12.4	0.2	263.69	177.16
S8C	R1	1874.471	50yrs	39.54	10	12.33	0.16	255.33	170.09
S8C	R1	1874.471	100yrs	52.93	10	12.4	0.2	267.89	171.84
S8C	R1	1801.469	50yrs	39.54	9.85	12.33	0.12	339.77	204.71
S8C	R1	1801.469	100yrs	52.93	9.85	12.4	0.16	354.84	206.87
S8C	R1	1752.49	50yrs	39.54	9.76	12.32	0.11	372.53	226.11
S8C	R1	1752.49	100yrs	52.93	9.76	12.4	0.15	389.14	228.44

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	1697.742		Culvert					
S8C	R1	1671.887	50yrs	39.54	9.63	10.26	1.02	38.63	74.74
S8C	R1	1671.887	100yrs	52.93	9.63	10.4	1.06	49.82	81.8
S8C	R1	1539.053	50yrs	39.54	9	9.93	0.88	45.18	84.52
S8C	R1	1539.053	100yrs	52.93	9	10.08	0.86	61.55	128.21
S8C	R1	1504.744	50yrs	39.54	8.94	9.84	1	39.48	65.25
S8C	R1	1504.744	100yrs	52.93	8.94	9.97	1.09	48.77	71.17
S8C	R1	1398.772	50yrs	39.54	8.87	9.71	0.66	60.1	89.11
S8C	R1	1398.772	100yrs	52.93	8.87	9.84	0.73	72.42	96.55
S8C	R1	1357.301	50yrs	39.54	8.84	9.5	1.63	24.31	52.32
S8C	R1	1357.301	100yrs	52.93	8.84	9.62	1.71	30.97	59.2
S8C	R1	1284.834	50yrs	39.54	8.64	9.3	0.91	43.25	70.89
S8C	R1	1284.834	100yrs	52.93	8.64	9.44	0.99	53.39	74
S8C	R1	1144.667	50yrs	39.54	8	9.06	0.83	47.53	73.37
S8C	R1	1144.667	100yrs	52.93	8	9.22	0.89	59.66	78.19

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	980.5778	50yrs	39.54	7.89	8.84	0.81	48.71	65.91
S8C	R1	980.5778	100yrs	52.93	7.89	9.01	0.87	60.57	71.26
S8C	R1	957.7596	50yrs	39.54	7.84	8.82	0.75	53.04	67.12
S8C	R1	957.7596	100yrs	52.93	7.84	8.99	0.81	65.13	72.06
S8C	R1	906.4235	50yrs	39.54	7.76	8.79	0.66	60.07	69.21
S8C	R1	906.4235	100yrs	52.93	7.76	8.96	0.73	72.42	73.56
S8C	R1	805.7545	50yrs	39.54	7.51	8.65	0.99	40.11	57.07
S8C	R1	805.7545	100yrs	52.93	7.51	8.82	1.05	50.32	62.73
S8C	R1	731.5229	50yrs	39.54	7.34	8.42	1.34	29.42	39.43
S8C	R1	731.5229	100yrs	52.93	7.34	8.58	1.47	36.11	42.98
S8C	R1	663.0113	50yrs	39.54	7.13	8.32	0.88	44.8	57.46
S8C	R1	663.0113	100yrs	52.93	7.13	8.49	0.97	54.72	63.02
S8C	R1	609.9108	50yrs	39.54	7	7.89	2.33	16.96	31.14
S8C	R1	609.9108	100yrs	52.93	7	8.04	2.42	21.88	37.27
S8C	R1	538.4608	50yrs	39.54	7	7.85	0.66	59.84	95.89
S8C	R1	538.4608	100yrs	52.93	7	7.96	0.75	70.75	100.48

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8C	R1	414.0357	50yrs	39.54	7	7.75	0.57	68.79	108.74
S8C	R1	414.0357	100yrs	52.93	7	7.85	0.67	79.56	113.19
S8C	R1	342.7026	50yrs	39.54	7	7.67	0.67	58.84	107.75
S8C	R1	342.7026	100yrs	52.93	7	7.76	0.78	68.04	112.87
S8C	R1	259.5312	50yrs	39.54	7	7.57	0.64	62	119.08
S8C	R1	259.5312	100yrs	52.93	7	7.64	0.76	69.29	121.28
S8B	R1	5906.39	50yrs	154.65	35	38.42	0.69	225.27	81.91
S8B	R1	5906.39	100yrs	207.75	35	38.7	0.84	248.1	84.19
S8B	R1	5881.57		Culvert					
S8B	R1	5856.871	50yrs	154.65	33.93	36.58	1.22	127.09	62.21
S8B	R1	5856.871	100yrs	207.75	33.93	36.97	1.37	151.45	64.77
S8B	R1	5791.262	50yrs	154.65	33.9	36.25	2.4	64.39	41.9
S8B	R1	5791.262	100yrs	207.75	33.9	36.59	2.62	79.17	45.2
S8B	R1	5735.621	50yrs	154.65	33.89	36.07	2.13	72.63	56.78
S8B	R1	5735.621	100yrs	207.75	33.89	36.47	2.16	96.37	61.51

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	5676.491	50yrs	154.65	33.85	36.16	0.67	230.03	183.53
S8B	R1	5676.491	100yrs	207.75	33.85	36.58	0.67	308.36	188.92
S8B	R1	5601.829	50yrs	154.65	33.78	36.07	1.18	130.97	70.21
S8B	R1	5601.829	100yrs	207.75	33.78	36.48	1.29	160.96	74.84
S8B	R1	5546.096	50yrs	154.65	33	35.3	3.64	42.45	31.47
S8B	R1	5546.096	100yrs	207.75	33	35.64	3.86	53.87	35.52
S8B	R1	5488.695	50yrs	154.65	32.62	33.62	4.97	31.1	33.15
S8B	R1	5488.695	100yrs	207.75	32.62	33.84	5.37	38.68	37.45
S8B	R1	5433.48	50yrs	154.65	32	33.68	1.35	114.66	132.54
S8B	R1	5433.48	100yrs	207.75	32	33.94	1.37	151.19	152.11
S8B	R1	5347.29	50yrs	154.65	31.9	33.55	1.16	133.49	107.54
S8B	R1	5347.29	100yrs	207.75	31.9	33.8	1.29	161.66	112.62
S8B	R1	5276.228	50yrs	154.65	31.68	33.38	1.49	103.47	90.54
S8B	R1	5276.228	100yrs	207.75	31.68	33.62	1.64	126.35	95.36
S8B	R1	5170.604	50yrs	154.65	31.05	32.55	2.91	53.23	62.24
S8B	R1	5170.604	100yrs	207.75	31.05	32.75	3.14	66.17	66.94

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	5072.125	50yrs	154.65	26.18	27.03	7.23	21.38	43.06
S8B	R1	5072.125	100yrs	207.75	26.18	27.16	7.51	27.65	54.53
S8B	R1	5034.563	50yrs	154.65	25	27.62	1.95	79.45	44.8
S8B	R1	5034.563	100yrs	207.75	25	28	2.15	96.77	47.7
S8B	R1	4989	50yrs	154.65	25	26.93	3.57	43.28	33.25
S8B	R1	4989	100yrs	207.75	25	27.25	3.82	54.33	36.45
S8B	R1	4944.514	50yrs	154.65	24.04	26.21	3.97	38.92	30.15
S8B	R1	4944.514	100yrs	207.75	24.04	26.52	4.24	48.96	33.71
S8B	R1	4880.748	50yrs	154.65	20	21.44	8.05	19.2	27.2
S8B	R1	4880.748	100yrs	207.75	20	21.62	8.27	25.13	40.16
S8B	R1	4823.913	50yrs	154.65	18	19.38	1.64	94.47	79.49
S8B	R1	4823.913	100yrs	207.75	18	19.67	1.76	117.94	81.79
S8B	R1	4773.724	50yrs	154.65	17.17	18.77	3.05	50.72	47.5
S8B	R1	4773.724	100yrs	207.75	17.17	19.05	3.22	64.46	51.29
S8B	R1	4716.826	50yrs	154.65	16.9	18.48	2.47	62.71	47.41
S8B	R1	4716.826	100yrs	207.75	16.9	18.76	2.71	76.77	51.44

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	4678.72	50yrs	154.65	16.86	18.38	2.06	74.99	58.48
S8B	R1	4678.72	100yrs	207.75	16.86	18.69	2.22	93.57	61.26
S8B	R1	4633.922	50yrs	154.65	16.8	18.35	1.44	107.33	73.86
S8B	R1	4633.922	100yrs	207.75	16.8	18.67	1.57	132.27	80.12
S8B	R1	4563.254	50yrs	154.65	16.7	18.13	1.85	83.45	60.57
S8B	R1	4563.254	100yrs	207.75	16.7	18.44	2.02	102.63	62.42
S8B	R1	4497.25	50yrs	154.65	16	18.1	1.19	130.11	82.68
S8B	R1	4497.25	100yrs	207.75	16	18.42	1.32	157.57	85.92
S8B	R1	4445.278	50yrs	154.65	15.8	18.02	1.34	115.42	67.86
S8B	R1	4445.278	100yrs	207.75	15.8	18.34	1.51	137.17	70.56
S8B	R1	4352.843	50yrs	154.65	15.77	17.88	1.45	106.71	75.16
S8B	R1	4352.843	100yrs	207.75	15.77	18.2	1.58	131.72	82.59
S8B	R1	4293.349	50yrs	154.65	15.66	17.77	1.55	99.78	69.11
S8B	R1	4293.349	100yrs	207.75	15.66	18.08	1.7	121.86	74.39
S8B	R1	4190.101	50yrs	154.65	15	17.63	1.46	112.06	77.94
S8B	R1	4190.101	100yrs	207.75	15	17.94	1.62	136.81	81.78

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	4106.575	50yrs	154.65	14.89	16.99	3.06	50.48	48.77
S8B	R1	4106.575	100yrs	207.75	14.89	17.2	3.4	61.18	52.15
S8B	R1	4033.717	50yrs	154.65	14.7	16.77	1.88	82.27	71.9
S8B	R1	4033.717	100yrs	207.75	14.7	17.04	2.02	102.76	78.14
S8B	R1	3957.619	50yrs	154.65	14.5	15.91	3.25	47.63	45.52
S8B	R1	3957.619	100yrs	207.75	14.5	16.2	3.35	62	54.24
S8B	R1	3862.702	50yrs	154.65	14.44	15.84	0.68	231.69	172.93
S8B	R1	3862.702	100yrs	207.75	14.44	16	0.81	260.13	182.57
S8B	R1	3757.456	50yrs	154.65	13.81	15.82	0.44	351.99	263.46
S8B	R1	3757.456	100yrs	207.75	13.81	15.98	0.53	394.83	270.23
S8B	R1	3703.175	50yrs	154.65	13.66	15.82	0.38	403.98	265.04
S8B	R1	3703.175	100yrs	207.75	13.66	15.98	0.47	446.4	268.44
S8B	R1	3676.266	50yrs	154.65	13.59	15.81	0.39	398.81	238.66
S8B	R1	3676.266	100yrs	207.75	13.59	15.97	0.47	438.07	252.75
S8B	R1	3641.529	50yrs	154.65	13.5	15.81	0.38	402.59	236.57
S8B	R1	3641.529	100yrs	207.75	13.5	15.97	0.47	440.09	242.76

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	3613.229	50yrs	154.65	13.48	15.81	0.4	393.83	238.68
S8B	R1	3613.229	100yrs	207.75	13.48	15.96	0.49	431.44	245.88
S8B	R1	3461.653	50yrs	154.65	13.2	15.8	0.41	383.11	214.49
S8B	R1	3461.653	100yrs	207.75	13.2	15.95	0.51	415.93	223.72
S8B	R1	3405.745	50yrs	154.65	12.8	15.79	0.41	378.49	212.57
S8B	R1	3405.745	100yrs	207.75	12.8	15.94	0.51	410.73	224
S8B	R1	3330.585		Culvert					
S8B	R1	3277.352	50yrs	154.65	12	13.27	0.36	427.34	357.87
S8B	R1	3277.352	100yrs	207.75	12	13.52	0.4	524.65	410.6
S8B	R1	3092.057	50yrs	154.65	11.58	12.96	2.1	73.8	84.62
S8B	R1	3092.057	100yrs	207.75	11.58	13.2	2.11	98.37	117.82
S8B	R1	2995.591	50yrs	154.65	11.46	12.85	1.13	138.36	113.41
S8B	R1	2995.591	100yrs	207.75	11.46	13.05	1.3	161.32	122.57
S8B	R1	2807.357	50yrs	154.65	11.21	12.72	0.83	185.82	144.51
S8B	R1	2807.357	100yrs	207.75	11.21	12.88	0.99	210.23	152.22

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	2645.881	50yrs	154.65	11	12.61	0.54	188.95	154.03
S8B	R1	2645.881	100yrs	207.75	11	12.74	0.64	209.38	157.18
S8B	R1	2567.498	50yrs	154.65	10.88	12.59	0.61	262.85	216.56
S8B	R1	2567.498	100yrs	207.75	10.88	12.72	0.75	291.08	232.56
S8B	R1	2500.055	50yrs	154.65	10.81	12.59	0.42	406.62	272.92
S8B	R1	2500.055	100yrs	207.75	10.81	12.72	0.52	441.21	280.04
S8B	R1	2381.598	50yrs	154.65	10.77	12.58	0.36	436.32	255.75
S8B	R1	2381.598	100yrs	207.75	10.77	12.7	0.45	467.44	258.76
S8B	R1	2295.905	50yrs	154.65	10.65	12.58	0.34	458.05	262.48
S8B	R1	2295.905	100yrs	207.75	10.65	12.69	0.42	489.3	265.74
S8B	R1	2222.213	50yrs	154.65	10.45	12.57	0.32	486.32	258.26
S8B	R1	2222.213	100yrs	207.75	10.45	12.69	0.4	516.52	260.52
S8B	R1	2161.884	50yrs	154.65	10	12.57	0.31	511.22	235.45
S8B	R1	2161.884	100yrs	207.75	10	12.68	0.39	538.55	239.09
S8B	R1	2082.611	50yrs	154.65	9.9	12.57	0.3	561.35	254.03
S8B	R1	2082.611	100yrs	207.75	9.9	12.68	0.39	590.56	258.54

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	2053.516	50yrs	154.65	9.88	12.57	0.27	591.43	270.88
S8B	R1	2053.516	100yrs	207.75	9.88	12.68	0.34	622.7	279.32
S8B	R1	2017.964	50yrs	154.65	9.78	12.57	0.17	941.82	358.66
S8B	R1	2017.964	100yrs	207.75	9.78	12.68	0.22	982.97	360.8
S8B	R1	1986.88	50yrs	154.65	9.74	12.57	0.18	879.44	334.82
S8B	R1	1986.88	100yrs	207.75	9.74	12.68	0.23	917.85	338.5
S8B	R1	1956.331	50yrs	154.65	9.72	12.57	0.21	789.3	315.37
S8B	R1	1956.331	100yrs	207.75	9.72	12.68	0.27	825.34	319.4
S8B	R1	1898.79	50yrs	154.65	9.7	12.56	0.28	616.39	283.3
S8B	R1	1898.79	100yrs	207.75	9.7	12.68	0.36	648.47	289.87
S8B	R1	1826.678	50yrs	154.65	9.68	12.56	0.25	639.28	274.37
S8B	R1	1826.678	100yrs	207.75	9.68	12.67	0.32	670.07	279.38
S8B	R1	1782.034		Culvert					
S8B	R1	1755.375	50yrs	154.65	9.39	10.35	1.05	147.84	178.78
S8B	R1	1755.375	100yrs	207.75	9.39	10.54	1.14	181.92	183.22

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	1667.824	50yrs	154.65	9	10.09	1.41	109.88	143.79
S8B	R1	1667.824	100yrs	207.75	9	10.31	1.47	141.67	153.85
S8B	R1	1633.095	50yrs	154.65	8.88	10.05	1.06	145.25	149.5
S8B	R1	1633.095	100yrs	207.75	8.88	10.27	1.16	179.3	162.36
S8B	R1	1550.151	50yrs	154.65	8.55	9.92	1.12	138	132.42
S8B	R1	1550.151	100yrs	207.75	8.55	10.13	1.24	167.78	149.93
S8B	R1	1430.335	50yrs	154.65	7.98	9.66	1.39	111.3	115.05
S8B	R1	1430.335	100yrs	207.75	7.98	9.85	1.56	133.93	125.29
S8B	R1	1323.205	50yrs	154.65	7.96	9.32	1.57	98.36	110.08
S8B	R1	1323.205	100yrs	207.75	7.96	9.47	1.8	115.27	116.78
S8B	R1	1254.105	50yrs	154.65	7.92	9.13	1.17	132.43	202.97
S8B	R1	1254.105	100yrs	207.75	7.92	9.31	1.22	169.83	209.61
S8B	R1	1180.81	50yrs	154.65	7.88	8.93	1.22	127.22	156.59
S8B	R1	1180.81	100yrs	207.75	7.88	9.11	1.3	160.37	204.8
S8B	R1	1149.279	50yrs	154.65	7.85	8.61	2.15	72.09	126.8
S8B	R1	1149.279	100yrs	207.75	7.85	8.82	2.08	99.67	144.37

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	1081.595	50yrs	154.65	7.37	8.49	1.18	131.01	129.97
S8B	R1	1081.595	100yrs	207.75	7.37	8.68	1.33	156.66	136.65
S8B	R1	991.8993	50yrs	154.65	7	8.2	1.55	99.91	133.9
S8B	R1	991.8993	100yrs	207.75	7	8.4	1.61	128.68	145.12
S8B	R1	926.2576	50yrs	154.65	6.94	8.1	1.06	145.72	141.64
S8B	R1	926.2576	100yrs	207.75	6.94	8.31	1.18	176.22	146.67
S8B	R1	870.0291	50yrs	154.65	6.85	8.05	0.9	172.41	151.57
S8B	R1	870.0291	100yrs	207.75	6.85	8.26	1.01	205.18	160.04
S8B	R1	814.8016	50yrs	154.65	6.82	7.89	1.45	106.54	137.9
S8B	R1	814.8016	100yrs	207.75	6.82	8.11	1.5	138.48	163.03
S8B	R1	778.9212	50yrs	154.65	6.77	7.88	0.9	171.9	161.23
S8B	R1	778.9212	100yrs	207.75	6.77	8.09	1.01	206.03	164.43
S8B	R1	727.935	50yrs	154.65	6.75	7.84	0.82	188.16	181.63
S8B	R1	727.935	100yrs	207.75	6.75	8.06	0.92	226.97	185.37
S8B	R1	662.8808	50yrs	154.65	6.72	7.82	0.65	239.57	221.97
S8B	R1	662.8808	100yrs	207.75	6.72	8.03	0.72	287.14	223.21

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S8B	R1	596.4152	50yrs	154.65	6.68	7.77	0.79	196.53	184.77
S8B	R1	596.4152	100yrs	207.75	6.68	7.98	0.88	235.67	186.27
S8B	R1	561.1452	50yrs	154.65	6.5	7.73	0.9	171.43	163.53
S8B	R1	561.1452	100yrs	207.75	6.5	7.93	1.01	206.55	174
S8B	R1	485.7272	50yrs	154.65	6	7.63	1	154.98	162.61
S8B	R1	485.7272	100yrs	207.75	6	7.84	1.1	189.26	170.85
S8B	R1	425.5858	50yrs	154.65	6	7.54	1.08	143.51	158.65
S8B	R1	425.5858	100yrs	207.75	6	7.74	1.17	177.65	170.74
S8B	R1	354.932	50yrs	154.65	6	7.44	1.03	149.72	135.54
S8B	R1	354.932	100yrs	207.75	6	7.65	1.17	177.59	142.72
S8B	R1	289.7703	50yrs	154.65	6	7.37	1.02	150.95	132.42
S8B	R1	289.7703	100yrs	207.75	6	7.56	1.18	176.78	138.15
S8B	R1	195.9553	50yrs	154.65	6	7.3	0.89	176.13	157.64
S8B	R1	195.9553	100yrs	207.75	6	7.48	1.03	205.76	166.6
S1D	R1	4803.531	50yrs	276.04	3.65	8.14	1.5	183.59	52.88
S1D	R1	4803.531	100yrs	372.89	3.65	8.65	1.77	210.91	53.48

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	4791.669		Culvert					
S1D	R1	4771.472	50yrs	276.04	3.62	6.25	0.68	404.05	229.92
S1D	R1	4771.472	100yrs	372.89	3.62	6.73	0.72	517.4	243.95
S1D	R1	4616.007	50yrs	276.04	3.5	6.25	0.42	662.98	271.79
S1D	R1	4616.007	100yrs	372.89	3.5	6.72	0.47	797.89	292.92
S1D	R1	4383.979	50yrs	276.04	3.45	6.24	0.31	886.75	361.19
S1D	R1	4383.979	100yrs	372.89	3.45	6.72	0.35	1061.14	367.13
S1D	R1	4321.796	50yrs	276.04	3.41	6.23	0.35	789.39	320.22
S1D	R1	4321.796	100yrs	372.89	3.41	6.71	0.4	945.33	333.27
S1D	R1	4245.166	50yrs	276.04	3.4	6.23	0.43	638.36	260.77
S1D	R1	4245.166	100yrs	372.89	3.4	6.7	0.49	765.15	270.89
S1D	R1	4187.791	50yrs	276.04	3.39	6.22	0.53	519.85	212.76
S1D	R1	4187.791	100yrs	372.89	3.39	6.69	0.6	623.05	221.75
S1D	R1	4140.922	50yrs	276.04	3.37	6.21	0.54	511.49	210.69
S1D	R1	4140.922	100yrs	372.89	3.37	6.68	0.61	613.37	218.34

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	4073.163	50yrs	276.04	3.35	6.11	1.37	202.18	81.38
S1D	R1	4073.163	100yrs	372.89	3.35	6.55	1.56	239.6	86.02
S1D	R1	3988.107	50yrs	276.04	3.32	6.14	0.58	478.69	190.83
S1D	R1	3988.107	100yrs	372.89	3.32	6.6	0.66	568.31	197.37
S1D	R1	3921.593	50yrs	276.04	3.31	6.12	0.71	391.22	173.47
S1D	R1	3921.593	100yrs	372.89	3.31	6.58	0.79	473.16	182.34
S1D	R1	3853.169	50yrs	276.04	3.3	5.72	2.65	104.02	55.76
S1D	R1	3853.169	100yrs	372.89	3.3	6.08	2.98	125.27	60.86
S1D	R1	3747.872	50yrs	276.04	3.29	5.68	1.58	174.48	83.92
S1D	R1	3747.872	100yrs	372.89	3.29	6.06	1.8	207.37	87.42
S1D	R1	3705.384	50yrs	276.04	3.28	5.67	1.27	218.08	105.09
S1D	R1	3705.384	100yrs	372.89	3.28	6.06	1.43	260.31	111.07
S1D	R1	3647.607	50yrs	276.04	3.27	5.53	1.75	157.6	74.93
S1D	R1	3647.607	100yrs	372.89	3.27	5.88	2.02	184.3	76.25
S1D	R1	3610.573	50yrs	276.04	3.25	5.45	1.86	148.05	76.58
S1D	R1	3610.573	100yrs	372.89	3.25	5.79	2.13	175.03	80.16

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	3513.644	50yrs	276.04	3.23	5.28	1.84	150.39	79.6
S1D	R1	3513.644	100yrs	372.89	3.23	5.6	2.11	176.59	81.76
S1D	R1	3445.509	50yrs	276.04	3.22	5.32	0.91	302.03	152.25
S1D	R1	3445.509	100yrs	372.89	3.22	5.67	1.05	355.86	156.1
S1D	R1	3363.522	50yrs	276.04	3.21	5.19	1.46	189.56	103.27
S1D	R1	3363.522	100yrs	372.89	3.21	5.51	1.67	223.21	106.27
S1D	R1	3316.822	50yrs	276.04	3.2	5.14	1.47	193.46	122.21
S1D	R1	3316.822	100yrs	372.89	3.2	5.46	1.65	234.31	133.16
S1D	R1	3234.104	50yrs	276.04	3.19	5.04	1.39	198.47	117.27
S1D	R1	3234.104	100yrs	372.89	3.19	5.35	1.58	235.56	120.87
S1D	R1	3174.74	50yrs	276.04	3.18	4.9	1.72	160.37	100.77
S1D	R1	3174.74	100yrs	372.89	3.18	5.18	1.97	189.48	103.39
S1D	R1	3094.609	50yrs	276.04	3.17	4.47	2.47	111.86	93.07
S1D	R1	3094.609	100yrs	372.89	3.17	4.58	3.05	122.38	94.1
S1D	R1	3005.24	50yrs	276.04	3.16	4.43	1.12	274.55	327.5
S1D	R1	3005.24	100yrs	372.89	3.16	4.63	1.22	342.27	334.21

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	2907.771	50yrs	276.04	3.15	4.35	0.83	334.18	303.86
S1D	R1	2907.771	100yrs	372.89	3.15	4.56	0.94	396.33	308.75
S1D	R1	2652.141	50yrs	276.04	3.13	4.24	0.6	466.74	440.25
S1D	R1	2652.141	100yrs	372.89	3.13	4.44	0.68	555.75	446.05
S1D	R1	2486.306	50yrs	276.04	3.1	4.12	0.86	320.22	324
S1D	R1	2486.306	100yrs	372.89	3.1	4.31	0.98	383.01	328.21
S1D	R1	2419.874	50yrs	276.04	3	4.07	0.83	333.93	324.44
S1D	R1	2419.874	100yrs	372.89	3	4.26	0.94	396.16	326.81
S1D	R1	2290.766	50yrs	276.04	2.9	3.93	0.96	287.49	290.86
S1D	R1	2290.766	100yrs	372.89	2.9	4.11	1.1	340.33	295.57
S1D	R1	2201.753	50yrs	276.04	2.8	3.83	0.96	287.3	292.48
S1D	R1	2201.753	100yrs	372.89	2.8	4	1.1	337.85	295.39
S1D	R1	2135.385	50yrs	276.04	2.7	3.76	0.92	300.84	304.98
S1D	R1	2135.385	100yrs	372.89	2.7	3.92	1.06	351.71	307.68
S1D	R1	2080.375	50yrs	276.04	2.6	3.69	0.95	291.87	299.84
S1D	R1	2080.375	100yrs	372.89	2.6	3.85	1.1	339.48	303.26

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	2039.121	50yrs	276.04	2.5	3.64	0.99	278.75	298.02
S1D	R1	2039.121	100yrs	372.89	2.5	3.79	1.15	323.56	299.84
S1D	R1	1922.648	50yrs	276.04	2.4	3.49	1.01	297.38	368.73
S1D	R1	1922.648	100yrs	372.89	2.4	3.63	1.17	346.57	373.48
S1D	R1	1831.815	50yrs	276.04	2.3	3.25	1.55	209.59	410.09
S1D	R1	1831.815	100yrs	372.89	2.3	3.34	1.79	246.3	417.05
S1D	R1	1789.691	50yrs	276.04	2.2	3.2	0.87	318.87	443.21
S1D	R1	1789.691	100yrs	372.89	2.2	3.27	1.06	351.09	449.01
S1D	R1	1507.751	50yrs	276.04	2.1	3.14	0.3	929.92	1010.04
S1D	R1	1507.751	100yrs	372.89	2.1	3.18	0.38	970.12	1019.22
S1D	R1	1418.828	50yrs	276.04	2	3.14	0.27	1024.93	946.95
S1D	R1	1418.828	100yrs	372.89	2	3.17	0.35	1057.61	947.93
S1D	R1	1225.045	50yrs	276.04	1.98	3.12	0.28	992.53	998.65
S1D	R1	1225.045	100yrs	372.89	1.98	3.14	0.37	1015.27	1003.74
S1D	R1	919.2166	50yrs	276.04	1.96	3.1	0.22	1270.58	1139.55
S1D	R1	919.2166	100yrs	372.89	1.96	3.11	0.29	1279.68	1139.9

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1D	R1	748.0336	50yrs	276.04	1.94	3.1	0.13	2150.13	1860.69
S1D	R1	748.0336	100yrs	372.89	1.94	3.1	0.17	2159.85	1860.71
S1D	R1	692.0188	50yrs	276.04	1.93	3.1	0.13	2063.98	1802.67
S1D	R1	692.0188	100yrs	372.89	1.93	3.1	0.18	2071.87	1802.91
S1D	R1	499.7875	50yrs	276.04	1.91	3.09	0.14	2007.53	1784.16
S1D	R1	499.7875	100yrs	372.89	1.91	3.09	0.19	2009.95	1784.35
S1D	R1	406.9292	50yrs	276.04	1.88	3.09	0.13	2089.86	1762.81
S1D	R1	406.9292	100yrs	372.89	1.88	3.09	0.18	2089.86	1762.81
S1B	R1	3720.686	50yrs	1352.7	2	3.09	11.78	114.84	117.13
S1B	R1	3720.686	100yrs	1836.56	2	3.09	15.99	114.84	117.13
S1B	R1	3615.816	50yrs	1352.7	1.99	6.28	2.37	571.95	148.91
S1B	R1	3615.816	100yrs	1836.56	1.99	6.9	2.76	665.07	153.02
S1B	R1	3505.526	50yrs	1352.7	1.98	6.21	2.11	642.41	169.78
S1B	R1	3505.526	100yrs	1836.56	1.98	6.83	2.47	748.19	174.45
S1B	R1	3435.605	50yrs	1352.7	1.98	6.17	1.99	680.27	179.69
S1B	R1	3435.605	100yrs	1836.56	1.98	6.78	2.33	791.73	184.45

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1B	R1	3268.421	50yrs	1352.7	1.98	6.13	1.47	920.11	255.17
S1B	R1	3268.421	100yrs	1836.56	1.98	6.76	1.71	1082.02	261.72
S1B	R1	3176.466	50yrs	1352.7	1.96	5.99	1.92	706.15	193.75
S1B	R1	3176.466	100yrs	1836.56	1.96	6.58	2.24	821.95	201.17
S1B	R1	3009.713	50yrs	1352.7	1.95	6.01	1.09	1249.35	336.55
S1B	R1	3009.713	100yrs	1836.56	1.95	6.62	1.27	1458.14	346.86
S1B	R1	2933.7	50yrs	1352.7	1.94	5.79	2.15	630.12	182.03
S1B	R1	2933.7	100yrs	1836.56	1.94	6.32	2.52	728.39	190
S1B	R1	2743.151	50yrs	1352.7	1.94	5.64	1.84	766.14	293.49
S1B	R1	2743.151	100yrs	1836.56	1.94	6.18	2.08	934.35	328.35
S1B	R1	2601.559	50yrs	1352.7	1.93	5.6	1.35	1003.92	310.88
S1B	R1	2601.559	100yrs	1836.56	1.93	6.14	1.56	1173.59	327.48
S1B	R1	2505.302	50yrs	1352.7	1.92	5.54	1.44	940.82	289.7
S1B	R1	2505.302	100yrs	1836.56	1.92	6.06	1.68	1093.38	296.57
S1B	R1	2339.53	50yrs	1352.7	1.91	5.44	1.47	931.96	341.49
S1B	R1	2339.53	100yrs	1836.56	1.91	5.96	1.68	1112.62	365.54

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1B	R1	2198.369	50yrs	1352.7	1.9	5.27	1.79	758.21	276.74
S1B	R1	2198.369	100yrs	1836.56	1.9	5.75	2.07	893.49	285.09
S1B	R1	2078.819	50yrs	1352.7	1.9	5.16	1.78	759.52	261.05
S1B	R1	2078.819	100yrs	1836.56	1.9	5.62	2.08	881.39	266.3
S1B	R1	1888.523	50yrs	1352.7	1.9	5.15	0.99	1364.32	458.47
S1B	R1	1888.523	100yrs	1836.56	1.9	5.63	1.16	1585.12	461.71
S1B	R1	1765.4	50yrs	1352.7	1.89	5.03	1.43	943.36	337.39
S1B	R1	1765.4	100yrs	1836.56	1.89	5.49	1.67	1096.86	342.36
S1B	R1	1649.836	50yrs	1352.7	1.88	4.92	1.62	833.06	310.51
S1B	R1	1649.836	100yrs	1836.56	1.88	5.34	1.9	967.35	316.77
S1B	R1	1547.876	50yrs	1352.7	1.88	4.83	1.61	877.81	372.43
S1B	R1	1547.876	100yrs	1836.56	1.88	5.26	1.86	1037.15	381.34
S1B	R1	1460.46	50yrs	1352.7	1.87	4.66	1.99	679.8	278.4
S1B	R1	1460.46	100yrs	1836.56	1.87	5.02	2.35	782.97	283.98
S1B	R1	1352.024	50yrs	1352.7	1.86	4.54	1.76	768.63	326.05
S1B	R1	1352.024	100yrs	1836.56	1.86	4.9	2.08	885.28	334.3

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1B	R1	712.218	50yrs	1352.7	1.85	3.59	1.68	847.44	638.63
S1B	R1	712.218	100yrs	1836.56	1.85	3.84	1.91	1007.77	649.35
S1B	R1	642.3395	50yrs	1352.7	1.85	3.09	2.68	528.95	643.76
S1B	R1	642.3395	100yrs	1836.56	1.85	3.23	3.11	618.34	650.68
S1A	R1	4476.778	1:50yr	1383.94	2	4.98	1.19	1167.2	420.79
S1A	R1	4476.778	1:100yr	1865.34	2	5.42	1.38	1353.08	425.39
S1A	R1	4318.321	1:50yr	1383.94	1.98	4.94	1.05	1394.58	543.45
S1A	R1	4318.321	1:100yr	1865.34	1.98	5.38	1.21	1635.08	550.94
S1A	R1	4148.306	1:50yr	1383.94	1.96	4.86	1.12	1239.31	451.15
S1A	R1	4148.306	1:100yr	1865.34	1.96	5.29	1.3	1431.8	453.46
S1A	R1	3934.591	1:50yr	1383.94	1.95	4.74	1.31	1077.25	423.42
S1A	R1	3934.591	1:100yr	1865.34	1.95	5.15	1.52	1249.62	428.38
S1A	R1	3663.042	1:50yr	1383.94	1.94	4.55	1.42	979.01	408.71
S1A	R1	3663.042	1:100yr	1865.34	1.94	4.92	1.66	1133.02	411.51
S1A	R1	3493.71	1:50yr	1383.94	1.93	4.34	1.69	822.63	376.23
S1A	R1	3493.71	1:100yr	1865.34	1.93	4.68	1.98	949.88	379.39

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1A	R1	3382.428	1:50yr	1383.94	1.92	4.22	1.61	866.29	421.16
S1A	R1	3382.428	1:100yr	1865.34	1.92	4.54	1.87	1003.66	430.24
S1A	R1	3259.355	1:50yr	1383.94	1.89	4.23	0.83	1659.53	733.19
S1A	R1	3259.355	1:100yr	1865.34	1.89	4.56	0.98	1907.72	735.76
S1A	R1	3082.551	1:50yr	1383.94	1.87	4.06	1.42	972.16	507.6
S1A	R1	3082.551	1:100yr	1865.34	1.87	4.36	1.66	1124.96	511.9
S1A	R1	3006.776	1:50yr	1383.94	1.86	3.95	1.57	883.29	461.33
S1A	R1	3006.776	1:100yr	1865.34	1.86	4.23	1.85	1010.38	464.62
S1A	R1	2870.922	1:50yr	1383.94	1.84	3.85	1.24	1122	627.98
S1A	R1	2870.922	1:100yr	1865.34	1.84	4.11	1.46	1290.09	635.49
S1A	R1	2754.378	1:50yr	1383.94	1.83	3.8	0.95	1450.76	785.98
S1A	R1	2754.378	1:100yr	1865.34	1.83	4.06	1.13	1657.35	793.52
S1A	R1	2712.052	1:50yr	1383.94	1.82	3.78	0.94	1479.46	788.44
S1A	R1	2712.052	1:100yr	1865.34	1.82	4.04	1.11	1683.33	793.18
S1A	R1	2492.364	1:50yr	1383.94	1.81	3.69	0.86	1605.69	901.54
S1A	R1	2492.364	1:100yr	1865.34	1.81	3.93	1.02	1823.74	907.08

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1A	R1	2361.928	1:50yr	1383.94	1.8	3.64	0.78	1784.9	984.29
S1A	R1	2361.928	1:100yr	1865.34	1.8	3.88	0.93	2014.96	993.31
S1A	R1	2300.187	1:50yr	1383.94	1.78	3.56	1.2	1151.81	708.13
S1A	R1	2300.187	1:100yr	1865.34	1.78	3.77	1.44	1297.64	716.94
S1A	R1	2225.476	1:50yr	1383.94	1.76	3.49	1.24	1119.33	700.44
S1A	R1	2225.476	1:100yr	1865.34	1.76	3.67	1.5	1247.42	707.22
S1A	R1	2168.681	1:50yr	1383.94	1.76	3.42	1.27	1099.54	724.12
S1A	R1	2168.681	1:100yr	1865.34	1.76	3.59	1.54	1216.98	733.13
S1A	R1	2124.464	1:50yr	1383.94	1.75	3.43	0.79	1743.25	1074.63
S1A	R1	2124.464	1:100yr	1865.34	1.75	3.6	0.97	1925.61	1078.71
S1A	R1	2069.956	1:50yr	1383.94	1.74	3.41	0.78	1767.57	1111.57
S1A	R1	2069.956	1:100yr	1865.34	1.74	3.57	0.96	1948.77	1116.22
S1A	R1	1449.698	1:50yr	1383.94	1.73	3.3	0.41	3400.67	2236.92
S1A	R1	1449.698	1:100yr	1865.34	1.73	3.43	0.51	3681.38	2243.73
S1A	R1	1374.28	1:50yr	1383.94	1.72	3.3	0.4	3495.25	2274.11
S1A	R1	1374.28	1:100yr	1865.34	1.72	3.42	0.49	3772.81	2276.79

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1A	R1	1295.343	1:50yr	1383.94	1.71	3.29	0.41	3356.35	2232
S1A	R1	1295.343	1:100yr	1865.34	1.71	3.4	0.52	3619.43	2233.57
S1A	R1	1015.219	1:50yr	1383.94	1.7	3.26	0.37	3720.49	2446.1
S1A	R1	1015.219	1:100yr	1865.34	1.7	3.36	0.47	3977.79	2447.27
S1A	R1	907.8842	1:50yr	1383.94	1.7	3.25	0.38	3609.44	2336.41
S1A	R1	907.8842	1:100yr	1865.34	1.7	3.35	0.49	3842.72	2336.8
S1A	R1	784.6996	1:50yr	1383.94	1.69	3.23	0.41	3413.51	2222.57
S1A	R1	784.6996	1:100yr	1865.34	1.69	3.33	0.52	3619.71	2223.73
S1A	R1	656.0068	1:50yr	1383.94	1.68	3.21	0.45	3079.56	2095.21
S1A	R1	656.0068	1:100yr	1865.34	1.68	3.3	0.57	3253.54	2101.61
S1A	R1	569.2374	1:50yr	1383.94	1.67	3.2	0.39	3546.36	2319
S1A	R1	569.2374	1:100yr	1865.34	1.67	3.28	0.5	3727.79	2319.86
S1A	R1	510.9095	1:50yr	1383.94	1.66	3.2	0.4	3445.58	2366.85
S1A	R1	510.9095	1:100yr	1865.34	1.66	3.27	0.52	3621.8	2373.95
S1A	R1	253.8754	1:50yr	1383.94	1.65	3.13	0.65	2132.37	1600.58
S1A	R1	253.8754	1:100yr	1865.34	1.65	3.17	0.85	2187.32	1607.25

River	Reach	River Station	Profile	Q Total	Minimum Channel Elevation	Water Surface Elevation	Velocity in Channel	Flow Area	Top Width
				(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
S1A	R1	112.8051	1:50yr	1383.94	1.64	3.09	0.62	2248.81	1624.22
S1A	R1	112.8051	1:100yr	1865.34	1.64	3.09	0.83	2248.81	1624.22

SRK Report Distribution Record

Report No. 515234/SRL_Surface Water

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