Appendix W

Human Health
Risk Assessment

DISCLAIMER

This disclaimer applies to and governs the disclosure and use of this Environmental Impact Statement ("EIS"), and by reading, using or relying on any part(s) of the EIS you accept this disclaimer in full.

This Environmental Impact Statement, including the Executive Summary, and all chapters of and attachments and appendices to it and all drawings, plans, models, designs, specifications, reports, photographs, surveys, calculations and other data and information in any format contained and/or referenced in it, is together with this disclaimer referred to as the "**EIS**".

Purpose of EIS

The EIS has been prepared by, for and on behalf of Wafi Mining Limited and Newcrest PNG 2 Limited (together the "**WGJV Participants**"), being the participants in the Wafi-Golpu Joint Venture ("**WGJV**") and the registered holders of exploration licences EL 440 and EL1105, for the sole purpose of an application (the "**Permit Application**") by them for environmental approval under the Environment Act 2000 (the "**Act**") for the proposed construction, operation and (ultimately) closure of an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management, and related support facilities and services (the "**Project**") in Morobe Province, Independent State of Papua New Guinea. The EIS was prepared with input from consultants engaged by the WGJV Participants and/or their related bodies corporate ("**Consultants**").

The Permit Application is to be lodged with the Conservation and Environment Protection Authority ("**CEPA**"), Independent State of Papua New Guinea.

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Reliance and Use

The EIS is intended and will be made available to CEPA, for review by CEPA and other applicable agencies of the Government of the Independent State of Papua New Guinea ("**Authorised Agencies**"), for the purpose of considering and assessing the Permit Application in accordance with the Act ("**Authorised Purpose**"), and for no other purpose whatsoever.

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This disclaimer must accompany every copy of the EIS.

The EIS is meant to be read as a whole, and any part of it should not be read or relied upon out of context.

Limits on investigation and information

The EIS is based in part on information not within the control of either the WGJV Participants or the Consultants. While the WGJV Participants and Consultants believe that the information contained in the EIS should be reliable under the conditions and subject to the limitations set forth in the EIS, they do not guarantee the accuracy of that information.

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While the WGJV Participants, their Related Bodies Corporate and Consultants believe that the information (including any opinions, forecasts or projections) contained in the EIS should be reliable under the conditions and subject to the limitations set out therein, and provide such information in good faith, they make no warranty, guarantee or promise, express or implied, that any of the information will be correct, accurate, complete or up to date, nor that such information will remain unchanged after the date of issue of the EIS to CEPA, nor that any forecasts or projections will be realised. Actual outcomes may vary materially and adversely from projected outcomes.

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- expressly disclaim any liability for any consequential, special, contingent or penal damages whatsoever.

The basis of the Consultants' engagement is that the Consultants' liability, whether under the law of contract, tort, statute, equity or otherwise, is limited as set out in the terms of their engagement with the WGJV Participants and/or their related bodies corporate.

Disclosure for Authorised Purpose

The WGJV Participants acknowledge and agree that, for the Authorised Purpose, the EIS may be:

- copied, reproduced and reprinted;
- published or disclosed in whole or in part, including being made available to the general public in accordance with section 55 of the Act. All publications and disclosures are subject to this disclaimer.

Development of Project subject to Approvals, Further Studies and Market and Operating Conditions

Any future development of the Project is subject to further studies, completion of statutory processes, receipt of all necessary or desirable Papua New Guinea Government and WGJV Participant approvals, and market and operating conditions.

Engineering design and other studies are continuing and aspects of the proposed Project design and timetable may change.

NEWCREST MINING LIMITED DISCLAIMER

Newcrest Mining Limited ("**Newcrest**") is the ultimate holding company of Newcrest PNG 2 Limited and any reference below to "Newcrest" or the "Company" includes both Newcrest Mining Limited and Newcrest PNG 2 Limited.

Forward Looking Statements

The EIS includes forward looking statements. Forward looking statements can generally be identified by the use of words such as "may", "will", "expect", "intend", "plan", "estimate", "anticipate", "continue", "outlook" and "guidance", or other similar words and may include, without limitation, statements regarding plans, strategies and objectives of management, anticipated production or construction commencement dates and expected costs or production outputs. The Company continues to distinguish between outlook and guidance. Guidance statements relate to the current financial year. Outlook statements relate to years subsequent to the current financial year.

Forward looking statements inherently involve known and unknown risks, uncertainties and other factors that may cause the Company's actual results, performance and achievements to differ materially from statements in this EIS. Relevant factors may include, but are not limited to, changes in commodity prices, foreign exchange fluctuations and general economic conditions, increased costs and demand for production inputs, the speculative nature of exploration and project development, including the risks of obtaining necessary licences and permits and diminishing quantities or grades of reserves, political and social risks, changes to the regulatory framework within which the Company operates or may in the future operate, environmental conditions including extreme weather conditions, recruitment and retention of personnel, industrial relations issues and litigation.

Forward looking statements are based on the Company's good faith assumptions as to the financial, market, regulatory and other relevant environments that will exist and affect the Company's business and operations in the future.

The Company does not give any assurance that the assumptions will prove to be correct. There may be other factors that could cause actual results or events not to be as anticipated, and many events are beyond the reasonable control of the Company. Readers are cautioned not to place undue reliance on forward looking statements. Forward looking statements in the EIS speak only at the date of issue. Except as required by applicable laws or regulations, the Company does not undertake any obligation to publicly update or revise any of the forward looking statements or to advise of any change in assumptions on which any such statement is based.

Non-IFRS Financial Information

Newcrest results are reported under International Financial Reporting Standards (IFRS) including EBIT and EBITDA. The EIS also includes non-IFRS information including Underlying profit (profit after tax before significant items attributable to owners of the parent company), All-In Sustaining Cost (determined in accordance with the World Gold Council Guidance Note on Non-GAAP Metrics released June 2013), AISC Margin (realised gold price less AISC per ounce sold (where expressed as USD), or realised gold price less AISC per ounce sold divided by realised gold price (where expressed as a %), Interest Coverage Ratio (EBITDA/Interest payable for the relevant period), Free cash flow (cash flow from operating activities less cash flow related to investing activities), EBITDA margin (EBITDA expressed as a percentage of revenue) and EBIT margin (EBIT expressed as a percentage of revenue). These measures are used internally by Management to assess the performance of the business and make decisions on the allocation of resources and are included in the EIS to provide greater understanding of the underlying performance of Newcrest's operations. The non-IFRS information has not been subject to audit or review by Newcrest's external auditor and should be used in addition to IFRS information.

Ore Reserves and Mineral Resources Reporting Requirements

As an Australian Company with securities listed on the Australian Securities Exchange (ASX), Newcrest is subject to Australian disclosure requirements and standards, including the requirements of the Corporations Act 2001 and the ASX. Investors should note that it is a requirement of the ASX listing rules that the reporting of Ore Reserves and Mineral Resources in Australia comply with the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code) and that Newcrest's Ore Reserve and Mineral Resource estimates comply with the JORC Code.

Competent Person's Statement

The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

HARMONY GOLD MINING COMPANY LIMITED DISCLAIMER

Harmony Gold Mining Company Limited ("**Harmony**") is the ultimate holding company of Wafi Mining Limited and any reference below to "Harmony" or the "Company" includes both Harmony Gold Mining Company Limited and Wafi Mining Limited.

Forward Looking Statements

These materials contain forward-looking statements within the meaning of the safe harbor provided by Section 21E of the Securities Exchange Act of 1934, as amended, and Section 27A of the Securities Act of 1933, as amended, with respect to our financial condition, results of operations, business strategies, operating efficiencies, competitive positions, growth opportunities for existing services, plans and objectives of management, markets for stock and other matters. These include all statements other than statements of historical fact, including, without limitation, any statements preceded by, followed by, or that include the words "targets", "believes", "expects", "aims", "intends", "will", "may", "anticipates", "would", "should", "could", "estimates", "forecast", "predict", "continue" or similar expressions or the negative thereof.

These forward-looking statements, including, among others, those relating to our future business prospects, revenues and income, wherever they may occur in this EIS and the exhibits to this EIS, are essentially estimates reflecting the best judgment of our senior management and involve a number of risks and uncertainties that could cause actual results to differ materially from those suggested by the forward-looking statements. As a consequence, these forward-looking statements should be considered in light of various important factors, including those set forth in these materials. Important factors that could cause actual results to differ materially from estimates or projections contained in the forward-looking statements include, without limitation: overall economic and business conditions in South Africa, Papua New Guinea, Australia and elsewhere, estimates of future earnings, and the sensitivity of earnings to the gold and other metals prices, estimates of future gold and other metals production and sales, estimates of future cash costs, estimates of future cash flows, and the sensitivity of cash flows to the gold and other metals prices, statements regarding future debt repayments, estimates of future capital expenditures, the success of our business strategy, development activities and other initiatives, estimates of reserves statements regarding future exploration results and the replacement of reserves, the ability to achieve anticipated efficiencies and other cost savings in connection with past and future acquisitions, fluctuations in the market price of gold, the occurrence of hazards associated with underground and surface gold mining, the occurrence of labour disruptions, power cost increases as well as power stoppages, fluctuations and usage constraints, supply chain shortages and increases in the prices of production imports, availability, terms and deployment of capital, changes in government regulation, particularly mining rights and environmental regulation, fluctuations in exchange rates, the adequacy of the Group's insurance coverage and socio-economic or political instability in South Africa and Papua New Guinea and other countries in which we operate.

For a more detailed discussion of such risks and other factors (such as availability of credit or other sources of financing), see the Company's latest Integrated Annual Report and Form 20-F which is on file with the Securities and Exchange Commission, as well as the Company's other Securities and Exchange Commission filings. The Company undertakes no obligation to update publicly or release any revisions to these forward-looking statements to reflect events or circumstances after the date of this EIS or to reflect the occurrence of unanticipated events, except as required by law.

Competent Person's Statement

The Wafi-Golpu Joint Venture is an unincorporated joint venture between a wholly-owned subsidiary of Harmony Gold Mining Company Limited and a wholly-owned subsidiary of Newcrest Mining Limited.

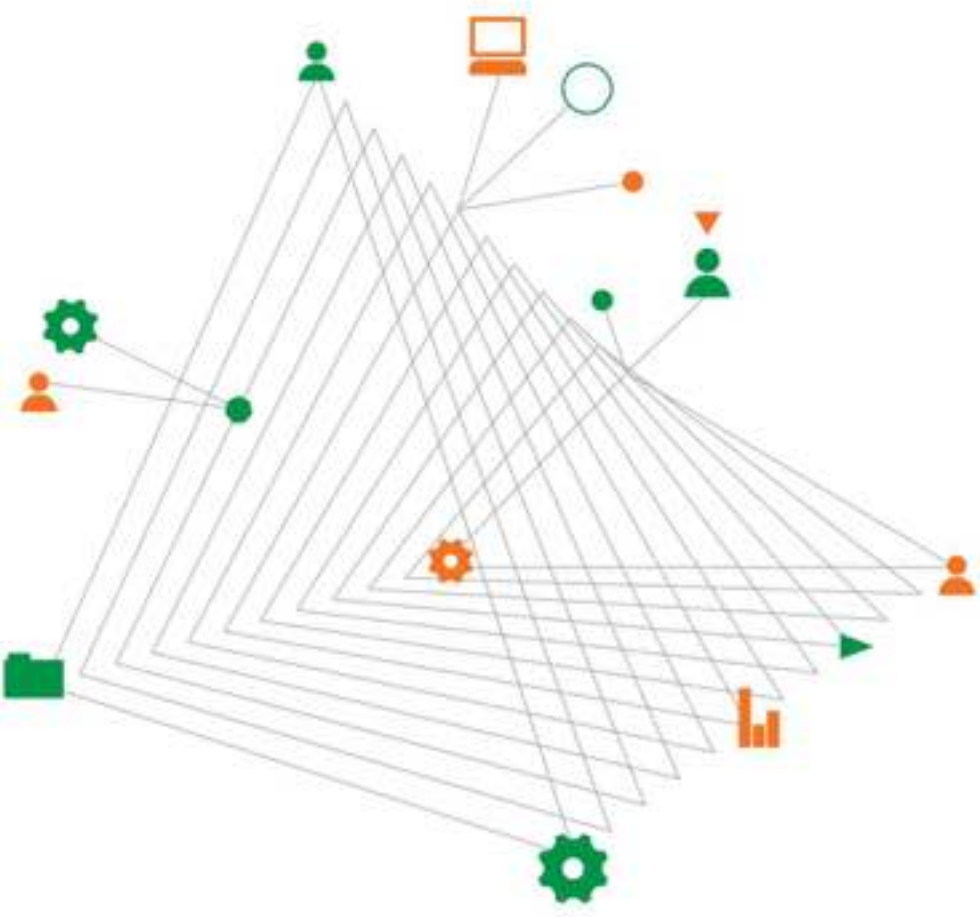
The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/ or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

Wafi-Golpu Joint Venture

Wafi-Golpu Project

Human Health Risk Assessment

June 2018



Experience comes to life when it is powered by expertise

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Wafi-Golpu Project

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Executive summary

Wafi Mining Limited and Newcrest PNG 2 Limited (WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV). The WGJV is investigating the feasibility of constructing, operating and (ultimately) closing an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management and related support facilities and services (Hereafter the “Wafi-Golpu Project” orthe “Project”), located beneath Mt Golpu, approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km south-west of Lae in the Morobe Province of the Independent State of Papua New Guinea (PNG). The Project includes ore processing, concentrate transport and handling, power generation, water management, a deep sea tailings placement (DSTP) system for tailings management, access roads to the mine and related support facilities.

Geographically, the Project occupies a mine to port footprint that extends from the Mine Area to the Coastal Area with an Infrastructure Corridor that links the two areas. Together these discrete areas make up the proposed Project Area:

- **Mine Area**. The area encompassing the proposed block cave mine, underground access declines and nearby infrastructure, including a portal terrace and waste rock dump supporting each of the Watut and Nambonga declines, the Watut Process Plant, power generation facilities, laydown areas, water treatment facilities, quarries, wastewater discharge and raw water make-up pipelines, raw water dam, sediment control structures, roads and accommodation facilities for the construction and operations workforces.
- **Infrastructure Corridor**. The area encompassing the proposed Project infrastructure linking the Mine Area and the Coastal Area, being corridors for pipelines and roads and associated laydown areas. The proposed concentrate pipeline, terrestrial tailings pipeline and fuel pipeline will connect the Mine Area to the Coastal Area. A proposed Mine Access Road and Northern Access Road will connect the Mine Area to the Highlands Highway. New single-lane bridges are proposed over the Markham, Watut and Bavaga rivers. Laydown areas will be located at key staging areas.
- **Coastal Area**. The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area:
  - Port Facilities Area. Located at, or in proximity to, the Port of Lae, with a site adjacent to Berth 6 (also known as Tanker Berth) nominated as the preferred option. The proposed facilities will include the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline.
  - Outfall Area. Located approximately six kilometres east of the port. The proposed facilities will include the Outfall System comprising the mix/de-aeration tank and associated facilities, seawater intake pipelines and DSTP outfall pipelines, pipeline laydown area, choke station, access track and parking turnaround area.

The WGJV has commissioned a range of studies to inform the Project’s Feasibility Study Update and to prepare an Environmental Impact Statement (EIS).

This report describes the findings of the Human Health Risk Assessment (HHRA) study. The HHRA is intended to inform the EIS of the following:

- Existing (baseline) risks to the health of human receptors.
- Potential human health risks associated with contaminants released to the environment as a result of proposed Project activities.

The HHRA outcomes will inform the need for mitigation measures where a potential human health risk associated with the proposed Project is identified, or the need for further investigations to refine the exposure model inputs.

The focus of the HHRA is on planned contaminant releases associated with waste discharges and emissions therefore unplanned events such as a rupture of the concentrate pipeline, terrestrial tailings pipeline or fuel pipeline are not addressed in this report.

Future development of the Project remains subject to ongoing deep orebody drilling and definition (after underground access has been achieved), technical studies, completion of statutory permitting processes and securing Government and WGJV Participants' approvals.

Engineering design and other studies, including environmental studies, are continuing and there is potential that aspects of the proposed Project design, layout and timetable may change.

Study areas

The report describes the methodology and findings of the HHRA baseline study and the predicted conditions relating to the Project in evaluating potential exposures to human populations within four defined study areas. The study areas were determined based on the locations of Project infrastructure and facilities that may release contaminants as a result of Project activities. The study areas include:

- Study Area 1: Mine Area, surrounds and access corridors.
- Study Area 2: Infrastructure Corridor from Zifasing to Lae.
- Study Area 3: Lae and Labu villages[1].
- Study Area 4: Wagang and Yanga villages.

This Executive Summary summarises the complete exposure pathways, and the key human health baseline findings and predicted outcomes associated with Project activities in each of the study areas.

HHRA methodology

The HHRA was undertaken in accordance with the Australian 'National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013'. This comprised a two-tiered approach involving qualitative (Tier 1) and quantitative assessments (Tier 2). The Tier 1 screening evaluations of baseline exposures to human receptors were undertaken based on a comparison of concentrations measured in media (i.e., air, sediment, water and food) with adopted screening criteria protective of human health, based on State of PNG and international guidelines and standards.

The baseline investigations used in the Tier 1 screening assessment included field sampling of freshwater and marine waters, sediments, air, and terrestrial and aquatic biota. The data collected during the surveys generally focussed on areas downstream of the Mine Area and the Huon Gulf.

Tier 1 – screening evaluation

The selected contaminants of potential concern for the Tier 1 assessment included metals, particulates, nitrogen dioxide and sulphur dioxide. The outcomes of the Tier 1 screening assessment found that zinc concentrations in freshwater fish and mercury levels in deep sea fish exceeded the adopted health screening criteria (Food Standards Australia and New Zealand, 2016). No other exceedances in any other media (e.g. water, air, sediment) were noted.

Tier 2 – exposure assessment

The exposure assessment considered intakes of contaminants for each possible complete pathway. An exposure pathway is only considered complete when all four of the following elements can be linked: a contaminant source (such as disturbed soil), transport/migration of the contaminant (such as in surface water runoff discharging to a creek) to a receptor (in this case a person) who is then exposed via an exposure route (such as ingestion of water). The receptors of concern selected for the quantitative Tier 2 evaluation were young children aged 0 to 5 years old and adults in each of the study areas. Young children are considered to be the more sensitive receptor population due to their

[1] For the purposes of the HHRA, villagers located near the Labu Lakes were also included in Study Area 3: Labu Bulu, Labumiti and Labu Tale.

weight to food intake ratios and hygiene behaviours, and therefore represent a conservative assessment.

The exposure pathways considered in the quantitative evaluation assessed potential exposures to contaminants in water and foods as presented below.

Bathing, washing and recreational activities:

- Incidental ingestion of water during bathing, cleaning and recreational activities such as swimming or fishing.
- Dermal (i.e., skin) contact with water during bathing, cleaning and recreational activities.

Food sources:

- Ingestion of drinking water from primary and secondary water sources.
- Ingestion of freshwater aquatic foods.
- Ingestion of marine foods.
- Ingestion of terrestrial locally grown, collected and hunted foods.

The general approach taken for the exposure assessment was to adopt exposure parameters that would reflect the typical experiences of the majority of the receptor group. Exposure parameters are inputs such as how many hours per day or days per year someone is exposed to a contaminant.

Adults and young children were evaluated separately as the relative intake for young children (aged 0 to 5 years) is known to differ from older children and adults based on weight to food intake ratios and hygiene behaviours. The exposure parameters and adopted contaminant of potential concern (COPC) concentrations were based on a mixture of average or maximum (i.e., 365 days per year) exposure parameters and average exposure concentrations. This results in a conservative estimate of the average population exposure and is likely to represent most of the population.

Human health – baseline conditions

The study areas of interest were selected based on proximity to Project activities and downstream locations where receptors may be affected. Potential impacts to villages in Study Area 2 were identified in the construction phase and likely to be short term. The impacts were assumed to be mitigated via management measures and hence were not considered further in the HHRA. The baseline assessment of Study Area 3 is considered to represent Labu villagers, those whose foods are sourced locally via garden crops, hunting, gathering and fishing, rather than store bought in Lae.

Contaminant sources and potential migration of these contaminants to nearby and downstream receptors in Study Areas 1, 3 and 4 were reviewed, in conjunction with social and dietary surveys of identified villages, to determine potentially complete exposure pathways. The Tier 1 screening evaluation, in conjunction with the findings of the human specimen analysis of blood, urine and hair collected in 2013, provided information for the identification of COPCs and potentially complete exposure pathways requiring further assessment.

The estimated risk of threshold health effects associated with calculated contaminant intakes from each exposure pathway is known as the Hazard Quotient (HQ), or Hazard Index (HI) if exposed to a contaminant via more than one pathway. Where the Hazard Quotient is less than one (1) the health risk is considered to be acceptable. Where the calculated Hazard Quotient is greater than one, additional data or information may be required to refine the exposure modelling inputs, or management procedures implemented to minimise potential exposures.

The selection of COPC in the Tier 2 assessment (arsenic, lead, mercury and zinc) were based on the Tier 1 evaluation of measured concentrations in baseline media, known chronic human toxicity and potential Project related contaminants. The outcomes of the Tier 2 baseline assessment are presented in Table ES1 for children and Table ES2 for adults. These are the human health risks that people are exposed to currently, i.e., prior to Project commencement.

Individual exposure pathway outcomes: Based on the available data, the exposure modelling and exposure parameters adopted, exposure pathways were identified as resulting in potential existing (i.e., baseline) intakes that may exceed the tolerable daily intake over chronic periods (i.e., over a lifetime for adults or 6 years for young children). The exposure pathways where the Hazard Quotient exceeded 1 relate to the existing ingestion of local fish associated with mercury:

- Young child receptors in all study areas, who may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) in locally obtained freshwater and/or marine fish from the Huon Gulf.
- Adult receptors in coastal study areas, who may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) in locally obtained marine fish from the Huon Gulf.

Multiple exposure pathway outcomes: Based on the available data, the exposure modelling and exposure parameters adopted, the calculated Hazard Index identified potential existing (i.e., baseline) intakes that may exceed the tolerable daily intake over chronic periods, where exposures to a COPC is via multiple exposure pathways, to the following:

- Young child receptors in all study areas, who may be exposed to elevated levels of mercury under baseline conditions where locally caught fish are consumed.
- Young child receptors in Study Area 1, who may be exposed to elevated levels of zinc under baseline conditions.
- Adult receptors in coastal villages in Study Areas 3 and 4, who may be exposed to elevated levels of mercury under baseline conditions.

Further refinement of the baseline exposure and media inputs would provide greater confidence in this result given the uncertainties associated with consumption rates which are currently estimated from other parts of PNG (in the absence of site-specific consumption rates), the conservative effects of the high laboratory limits of reporting for some of the historical data on the calculated average concentrations adopted, and the conservative assumption that measured mercury in aquatic biota is in the more toxic organic form of methylmercury.

The analysis of human specimens such as blood, urine or hair indicated that individuals in Study Area 1 and Study Area 3 are currently exposed to elevated levels of some COPCs. The concentrations of mercury, lead and arsenic in human specimens collected from villagers in Study Area 3 reported exceedances of the adopted criteria. Arsenic levels measured in urine specimens in Study Area 1 were observed at concentrations exceeding adopted screening criteria, however it was noted a significantly larger percentage of participants from Study Area 3 villages exceeded the screening criteria.

Table ES1: Estimated Hazard Quotient outcomes for young children (0 to 5 years old) in the current environment (prior to Project commencement)

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water - secondary source	Incidental ingestion of water bathing / cleaning / washing purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing & gardening activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crustaceans	Ingestion of local molluscs	Hazard Index
Study Area 1 (Tier 1)	Arsenic	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Green
	Lead	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Green
	Mercury	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Grey	Orange
	Zinc	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Orange
Study Area 1 (Tier 2)	Arsenic	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Green
	Lead	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Green
	Mercury	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Grey	Orange
	Zinc	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Grey	Orange
Study Area 3	Arsenic	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Green	Green	Green
	Lead	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Green	Green	Green
	Mercury	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Orange	Green	Green	Orange
	Zinc	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Green	Green	Green
Study Area 4	Arsenic	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Grey	Grey	Green
	Lead	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Grey	Grey	Green
	Mercury	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Orange	Grey	Grey	Orange
	Zinc	Grey	Grey	Grey	Green	Grey	Green	Green	Green	Green	Green	Grey	Grey	Green

Green shaded cells indicate the potential exposures for the exposure scenario have been identified as low and tolerable

Grey shaded cells indicate data was not available for these study areas.

Orange shaded cells indicate an exposure exceeding the tolerable daily intake has been identified and further refinement of risk inputs or management may be required for this pathway.

Table ES2: Estimated Hazard Quotient outcomes in adults in the current environment (prior to Project commencement)

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water - secondary source	Incidental ingestion of water bathing / cleaning / washing purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing & gardening activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crustaceans	Ingestion of local molluscs	Hazard Index
Study Area 1 (Tier 1)	Arsenic													
	Lead													
	Mercury													
	Zinc													
Study Area 1 (Tier 2)	Arsenic													
	Lead													
	Mercury													
	Zinc													
Study Area 3	Arsenic													
	Lead													
	Mercury													
	Zinc													
Study Area 4	Arsenic													
	Lead													
	Mercury													
	Zinc													

Green shaded cells indicate the potential exposures for the exposure scenario have been identified as low and tolerable
Grey shaded cells indicate data was not available for these study areas.
Orange shaded cells indicate an exposure exceeding the tolerable daily intake has been identified and further refinement of risk inputs or management may be required for this pathway.

Human health – modelled predicted Project conditions

Following the evaluation of baseline conditions in the selected study areas, the potential impacts to these areas, as a result of discharges relating to Project activities, were assessed. Management measures are proposed to address potential releases of contaminants to the environment during the construction of the mine, access roads, and associated facilities, as well as during the mine operations. Mine tailings will be piped to the Outfall Area for disposal into the Huon Gulf and mine waste waters inclusive of sewage waters will be treated if required prior to discharge to the Lower Watut River. Modelling was undertaken to assess the potential effects of these discharges.

The predicted surface water concentrations of dissolved metal contaminants relating to Project wastewater discharges in Study Area 1 were based on modelled results from BMT WBM (2018b). The modelling results were presented for assessment points downstream of the proposed discharge location.

The maximum concentrations of predicted dissolved metal concentrations at assessment points downstream of the discharge point were below the adopted Tier 1 screening criteria for drinking water. Therefore, further quantitative Tier 2 modelling was not warranted. Based on the modelling outcomes of the COPC concentrations estimated in receiving waterways, the health risks associated with the proposed wastewater discharge pipeline to the Lower Watut River were considered to be low on the basis the predicted concentrations were below the adopted screening criteria.

Air quality modelling undertaken by SLR (2018) predicted emissions during intermediate fuel oil (IFO) power generation operation may exceed the SO_2 screening criteria at two locations, Ziriruk and Fly Camp. The modelling outcomes indicate villagers at these locations are potentially exposed to elevated levels of SO_2 for chronic exposure period during the operation phase of the mine. The WGJV is committed to achieving compliance with the adopted air quality criteria, and management measures such as scrubbers on the power generation facilities' stacks or increasing the exhaust gas exit velocity will be implemented to achieve compliance.

Review of potential impacts to human health associated with Deep Sea Tailings Placement

The Project proposes DSTP to manage tailings. The proposed Outfall Area is located east of Wagang, in Study Area 4. Potential community concerns about the use of DSTP include potential direct health effects from consumption of contaminated fish, economic loss from decreased subsistence fishing resources, and reduction in tourism at Wagang beach.

The pelagic, deep-slope and benthic environment of the Huon Gulf has low biodiversity as a result of the riverine sediment discharge, deposition and regular mass movements (underwater landslides). These same riverine sediments will also mingle with and bury the co-deposited tailings during operations and post-closure, respectively, and are predicted to promote rapid benthic recovery to pre-mine (baseline) conditions. Numerous rivers, notably the Markham and Busu rivers near the outfall site, contribute about 50 Mtpa of sediment to the Huon Gulf, augmented by ten other rivers along the north shore of the Huon Gulf which contribute another 10 Mtpa (Tetra Tech, 2018a). The introduction of some 16.5Mt of tailings via DSTP per annum will mix with the currently estimated natural background riverine suspended sediment load of approximately 60 Mtpa. The receiving area for the sediments has low diversity and low abundance in terms of edible fish species.

Huon Gulf DSTP metal bioaccumulation and biomagnification study

A detailed study was undertaken by Tetra Tech (2018a) to evaluate the bioavailability of metals in the Project tailings discharge to the Huon Gulf, and the biological pathways by which metals could be accumulated in fish that people consume. This report is provided as Appendix N to the EIS.

The study used predicted environmental metal concentrations derived from site-specific three-dimensional modelling and trophic pathway analysis to incorporate both bioconcentration and bioaccumulation of metals in each trophic level (zooplankton, micronekton and fish). The evaluation adopted species-specific ingestion rates and standard bioconcentration and bioaccumulation factors for each metal and it was conservatively assumed that each trophic level and fish species was exposed to bioavailable metals continuously.

Results of the screening analysis indicate that, with the possible exception of mercury, fish tissue concentrations of metals are predicted to be low and unlikely to exceed Food Standards Australia New Zealand (FSANZ, 2016b) guidelines. Mercury reported in fish tissue is assumed to be present as a result of natural or anthropogenic sources. On the basis that tailings studies undertaken for this Project indicate mercury concentrations in tailings liquor were below the ANZECC marine guidelines for 95% species protection level (ANZECC/ARMCANZ, 2000), any predicted bioaccumulation of mercury is not considered to be as a result of the proposed DSTP.

The estimated fish tissue concentrations of metals in the bioaccumulation study are similar to those measured at DSTP sites in the region (such as Lihir and Batu Hijau) over the past several years indicating that the predictions are robust. Probable fish tissue metal concentrations are likely to be even lower than predicted in the screening model if observed movement patterns of biota in the Huon Gulf are considered (e.g., diel migrations of plankton and micronekton, and area use of upper trophic level fish).

Tissue concentrations for copper, zinc, nickel, and manganese do not biomagnify in fish that people consume, and bioaccumulation factors follow a similar pattern across all trophic levels for all metals. Data collected thus far from the Huon Gulf suggest that arsenic and mercury may be bioaccumulated at higher concentrations in fish and that current conditions in the Huon Gulf, without DSTP, suggest that fish consumed by people in Huon Gulf may already exceed food safety guidelines for arsenic as well as mercury and that the use of DSTP will not make a discernible contribution to fish tissue metal concentrations beyond existing baseline levels.

Overall, the assessment of metal bioaccumulation and the review of several studies of projects with similar DSTP systems indicate that fish resources used by subsistence fishermen are unlikely to be contaminated as a result of the DSTP and consumption of these resources will not pose a human health risk. The concentration of manganese is predicted to double the observed background range as a result of DSTP, however the predicted concentration is relatively low compared to amounts of manganese required in the human diet. The results of trophic pathway modelling indicate that there is limited biomagnification of most metals in upper trophic level fish, and fish tissue metal concentrations that are currently below food safety guidelines are likely to remain so with DSTP in the Huon Gulf. Therefore, DSTP is not predicted to pose a human health risk to Study Area 3 and Study Area 4 communities.

Contents

Figures

Tables

Appendices

Glossary

Terms

acute exposure	A single exposure to a substance which results in severe biological harm or death. Acute exposures are usually characterised as lasting no longer than a day, as compared to longer, continuing exposure over a period of time.
aquifer	A layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) which may store or transmit groundwater.
artisanal fisheries	Traditional fisheries involving fishing households (as opposed to commercial companies), relatively small fishing vessels, making short fishing trips, close to shore, mainly for local consumption.
bioaccumulation	The net accumulation of a substance by an organism as a result of uptake directly from all environmental sources, including food.
bioconcentration	A process by which there is net accumulation of a chemical directly from an exposure medium into an organism.
biomagnification	The increasing concentration of a substance, such as a chemical, in the tissues of organisms at successively higher levels in a food chain. Also known as bioamplification.
biota	The animal and plant life of a particular region, habitat, or geological period.
block caving	An underground hard rock mining method that involves undermining an ore body, allowing it to progressively collapse under its own weight as a means of breaking and extracting the ore.
borrow pit	An area where material is extracted for use at another location, typically for construction or engineering uses.
chemicals of potential concern	Substances that are identified as being present and potentially hazardous.
chronic exposure	Where contact with a substance occurs over a long period of time.
Coastal Area	The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area.
decline	A sloping underground tunnel excavated for mobile equipment access from surface or from level to level.
dermal contact exposure	Contact of a substance with the skin.
detection limit	The lowest concentration of a substance than can reliably be distinguished from a zero concentration.
diel	A 24-hour period usually involving a day and the adjoining night.
dose	The quantity of a substance a person is exposed to over a defined period of time. An absorbed dose refers to the amount of a substance that enters the body via the skin, digestive system or lungs.
exposure	Contact by a receptor with a substance.

exposure assessment	The process of evaluating how people may be exposed to a substance and estimating the type and magnitude of their exposures, such as which exposure route, how often and for how long.
exposure pathway	The course a contaminant takes from the source to the point where a person may be exposed and the route the exposure occurs.
exposure route	The way a substance comes into contact with a receptor.
Geochemical Abundance Index	A measure of the enrichment of elements in whole rock samples. The Geochemical Abundance Index (GAI) compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a particular rock type). The main purpose of the GAI is to provide an indication of any elemental enrichment that may be of environmental importance.
Hazard Index	The sum of more than one Hazard Quotient for multiple substances and/or multiple exposure pathways.
Hazard Quotient	The ratio of the exposure intake of a substance via a particular exposure pathway to the toxicity reference dose for that substance over similar exposure periods.
Infrastructure Corridor	The area encompassing the proposed Project infrastructure linking the Mine Area and the Coastal Area, being corridors for pipelines and roads and associated laydown areas. The proposed concentrate pipeline, terrestrial tailings pipeline and fuel pipeline will connect the Mine Area to the Coastal Area. A proposed Mine Access Road and Northern Access Road will connect the Mine Area to the Highlands Highway. New single-lane bridges are proposed over the Markham, Watut and Bavaga rivers. Laydown areas will be located at key staging areas.
meiofauna	Multicellular animals between 50µm and 500µm in length that live in soil and aquatic sediments.
micronekton	Very small crustacean and other free-swimming marine animals.
Mine Area	The area encompassing the proposed block cave mine, underground access declines and nearby infrastructure, including a portal terrace and waste rock dump supporting each of the Watut and Nambonga declines, the Watut Process Plant, power generation facilities, laydown areas, water treatment facilities, quarries, wastewater discharge and raw water make-up pipelines, raw water dam, sediment control structures, roads and accommodation facilities for the construction and operations workforces.
nearshore	The region of the sea or seabed relatively close to the shore.
Outfall Area	The area encompassing the Outfall System, pipeline laydown area, choke station, access track and parking and turnaround area.
Outfall System	Includes mix/de-aeration tank, seawater intake pipelines and DSTP outfall pipelines. Located in the Outfall Area.
pelagic	Of, or relating to, living in open oceans or seas; living at or near the surface of the ocean, far from land, especially relating to fish.
point of exposure	The location where a person may come into contact with a substance.
Port Area	Port of Lae including Lae Tidal Basin and surrounds.
Port Facilities Area	Located at, or in proximity to, the Port of Lae, with a site adjacent to Berth 6 (also known as Tanker Berth) nominated as the preferred option. The proposed facilities will include the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline. This area may in the future need to include fuel oil handling and storage facilities.

Project	The Wafi-Golpu Project.
Project Area	The land that is the subject of the proposed Project activities and Project facilities, being: • The Mine Area. • The Infrastructure Corridor. • The Coastal Area.
receptor population	A group of people identified within a specified area and/or sharing similar characteristics.
risk	The probability that a substance may cause harm.
study areas	Any of the four study areas as defined in Section 3.2 of this report, being: • Study Area 1: Mine Area, surrounds and access corridors. • Study Area 2: Infrastructure Corridor from Zifasing to Lae. • Study Area 3: Lae. • Study Area 4: Wagang and Yanga villages.
tailings	The fine-grained rock particles remaining after the recoverable metals and minerals have been extracted from mined ore, and any remaining process water.
tolerable daily intake	The amount of a contaminant, expressed on a body weight basis that can be ingested over a day without appreciable risk to health.
tolerable intake	The amount of a contaminant, expressed on a body weight basis that can be ingested over a lifetime without appreciable risk to health.
toxicity	The degree of harmful effects posed by a substance to humans or other receptors.
transport pathway	The potential transport mechanisms following release of a contaminant.
trophic level	The group of organisms within an ecosystem which occupy the same level in a food chain.
vulnerable groups	Defined by the IFC Performance Standards on Environmental and Social Sustainability as people who are disadvantaged as a result of race, colour, sex, language, religion, political opinion or origin, gender, age, culture, literacy, sickness, physical or mental disability, economic status or dependence on unique natural resources.
Wafi-Golpu Joint Venture	An unincorporated joint venture between the Wafi-Golpu Joint Venture Participants.
WGJV Participants	The participants in the Wafi-Golpu Joint Venture, at the date of this Environmental Impact Statement, being presently Wafi Mining Limited and Newcrest PNG 2 Limited.

Abbreviations

µg/kg	micrograms per kilogram
µg/L	micrograms per litre
ADI	acceptable daily intake
AMD	acid and metalliferous drainage
ATSDR	Agency for Toxic Substances and Disease Registry (US)
bw	body weight
CDC	Centres for Disease Control and Prevention (US)
CEH	Centre for Environmental Health
COPC	contaminant of potential concern
CSM	conceptual site model
DSTP	deep sea tailings placement
FSANZ	Food Standards Australia New Zealand
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IFO	intermediate fuel oil
JECFA	WHO/FAO Joint Evaluation Committee for Food Additives
km	kilometre(s)
LOR	laboratory limit of reporting
m	metre(s)
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per litre
Mtpa	Million tonnes per annum
NAF	non-acid forming
NEPC	National Environment Protection Council (Australia)
NEPM	National Environment Protection (Assessment of Site Contamination) Measure (Australia)
NHMRC	National Health and Medical Research Council
NOAEL	no observed adverse effect level
NO_x	oxides of nitrogen
PAF	potentially acid forming
PM_{10}	respirable particulates less than 2.5 microns
$PM_{2.5}$	respirable particulates less than 10 microns
POE	point of exposure
PNG	Papua New Guinea
RAGS	Risk Assessment Guidance for Superfund
SAMS	Scottish Association for Marine Science
TDI	tolerable daily intake
TRV	toxicity reference value
US EPA	United States Environmental Protection Agency
WGJV	Wafi-Golpu Joint Venture
WHO	World Health Organization
ww	wet weight
µg/kg	micrograms per kilogram
µg/kg/day	micrograms per kilogram per day
µg/L	micrograms per litre

1 Introduction

Wafi Mining Limited and Newcrest PNG 2 Limited (WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV). The WGJV is investigating the feasibility of constructing, operating and (ultimately) closing an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management and related support facilities and services (Hereafter the "Wafi-Golpu Project" or the "Project"), located beneath Mt Golpu, approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km south-west of Lae in the Morobe Province of the Independent State of Papua New Guinea (PNG). The Project location is shown in Figure 1.1. The Project includes ore processing, concentrate transport and handling, power generation, water management, a deep sea tailings placement (DSTP) system for tailings management, access roads to the mine and related support facilities.

Geographically, the Project occupies a mine to port footprint that extends from the Mine Area to the Coastal Area with an Infrastructure Corridor that links the two areas. Together these discrete areas make up the proposed Project Area:

- **Mine Area**. The area encompassing the proposed block cave mine, underground access declines and nearby infrastructure, including a portal terrace and waste rock dump supporting each of the Watut and Nambonga declines, the Watut Process Plant, power generation facilities, laydown areas, water treatment facilities, quarries, wastewater discharge and raw water make-up pipelines, raw water dam, sediment control structures, roads and accommodation facilities for the construction and operations workforces.
- **Infrastructure Corridor**. The area encompassing the proposed Project infrastructure linking the Mine Area and the Coastal Area, being corridors for pipelines and roads and associated laydown areas. The proposed concentrate pipeline, terrestrial tailings pipeline and fuel pipeline will connect the Mine Area to the Coastal Area. A proposed Mine Access Road and Northern Access Road will connect the Mine Area to the Highlands Highway. New single-lane bridges are proposed over the Markham, Watut and Bavaga rivers. Laydown areas will be located at key staging areas.
- **Coastal Area**. The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area:
  - Port Facilities Area. Located at, or in proximity to, the Port of Lae, with a site adjacent to Berth 6 (also known as Tanker Berth) nominated as the preferred option. The proposed facilities will include the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline.
  - Outfall Area. Located approximately six kilometres east of the port. The proposed facilities will include the Outfall System comprising the mix/de-aeration tank and associated facilities, seawater intake pipelines and DSTP outfall pipelines, pipeline laydown area, choke station, access track and parking turnaround area.

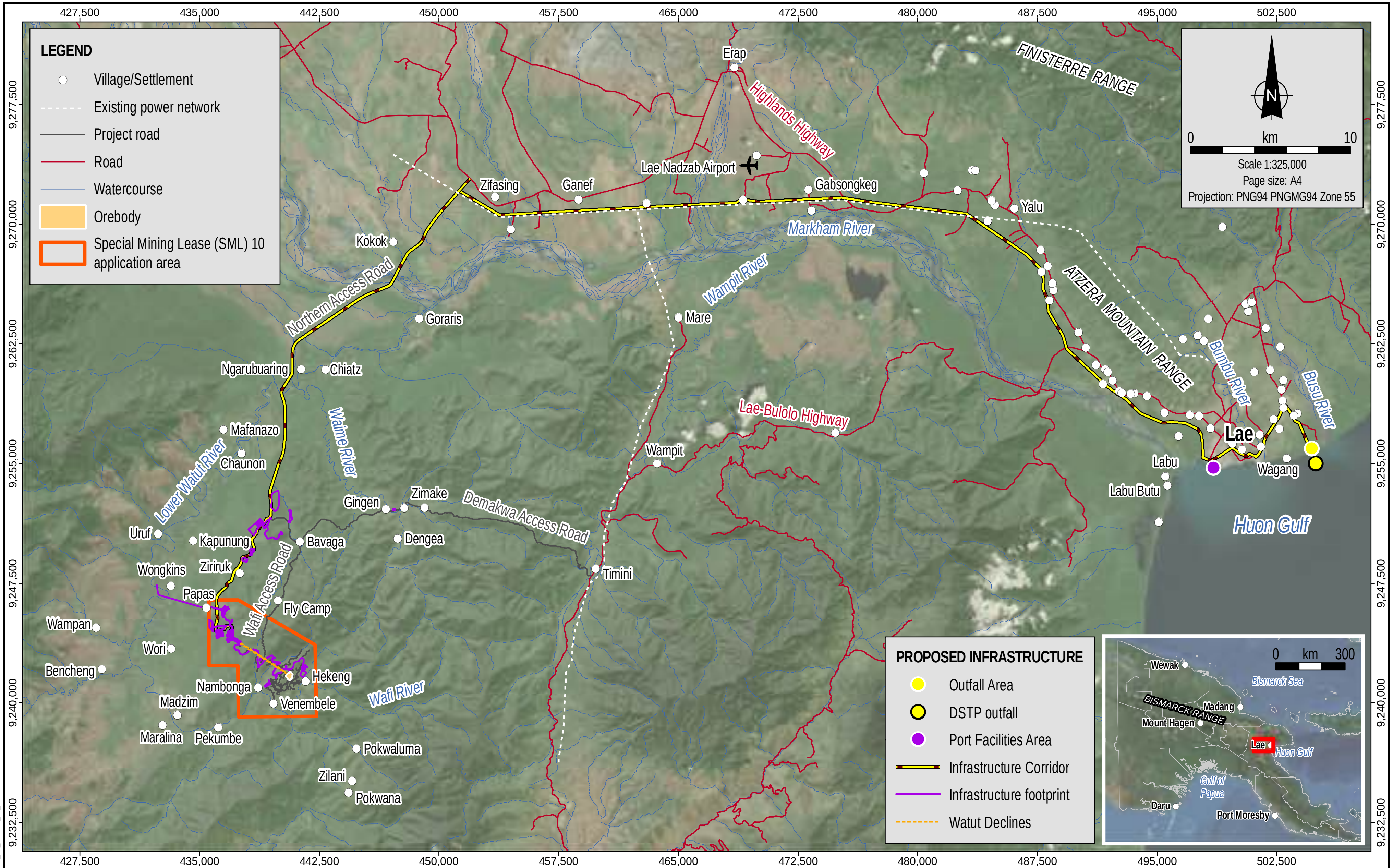
The Project overview is presented in Figure 1.2. and the Coastal Area is shown in more detail on Figure 1.3.

The WGJV has commissioned a range of studies to inform the Project's Feasibility Study Update and to prepare an Environmental Impact Statement (EIS).

This report describes the findings of the Human Health Risk Assessment study. The study area for this report is defined in Section 1.1.

Future development of the Project remains subject to ongoing deep orebody drilling and definition (after underground access has been achieved), technical studies, completion of statutory permitting processes and securing Government and WGJV Participants' approvals.

Engineering design and other studies, including environmental studies, are continuing and there is potential that aspects of the proposed Project design, layout and timetable may change.



MXD Reference: 0520DD_23_GIS001_v0_3

Source:
Power network, SML and orebody from WGJV.
Villages, infrastructure and project roads from WGJV and Coffey.
Roads and watercourses from NSO.
Imagery from ArcGIS Online (capture date unknown).

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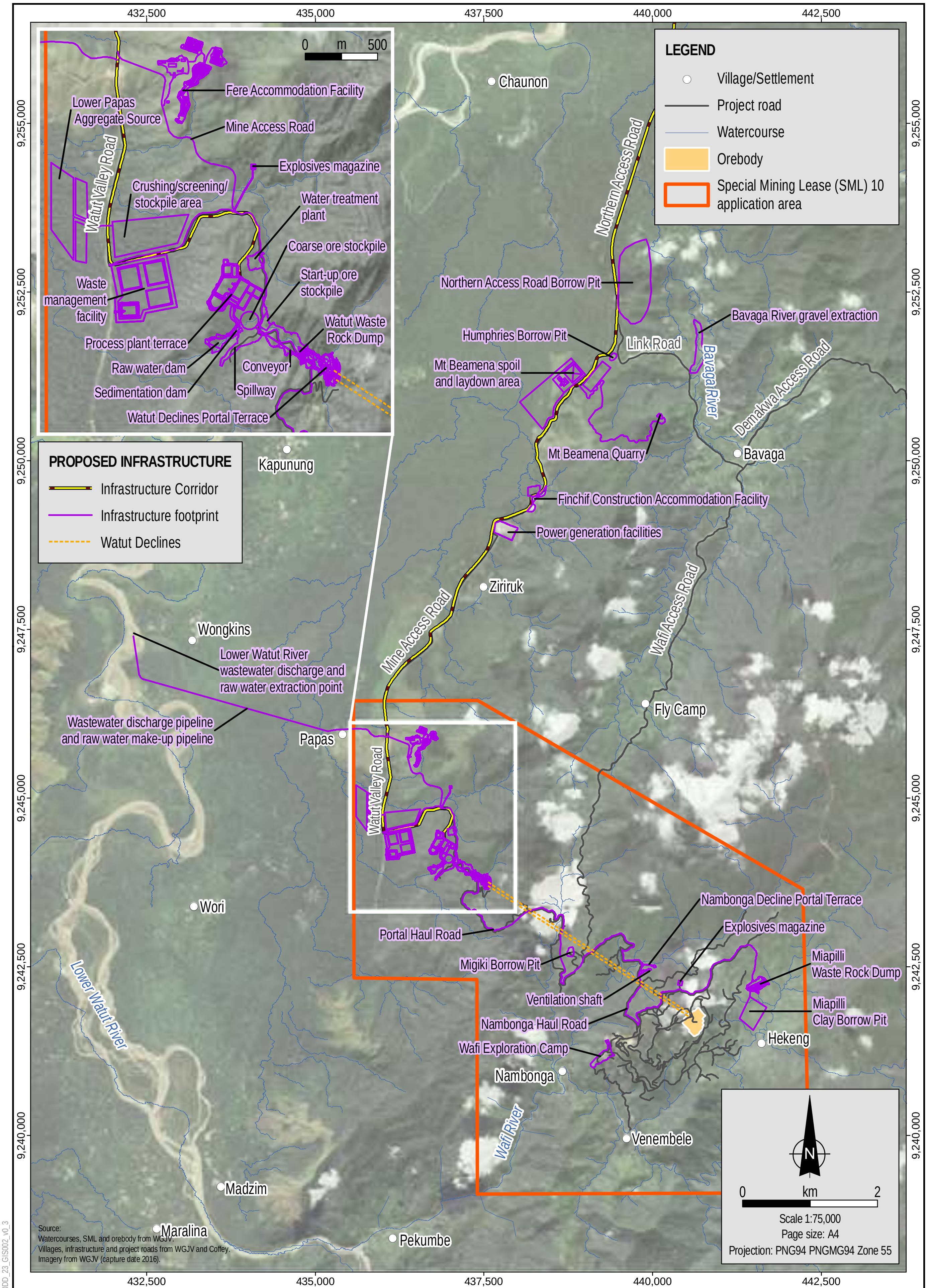
Date: 26.04.2018
Project: 754-ENAUABTF100520DD
File Name: 0520DD_23_F01.01_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Project location

Figure No: 1.1



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Date: 26.04.2018	WAFI-GOLPU JOINT VENTURE	Mine Area overview	Figure No: 1.2
Project: 754-ENAUABTF100520DD	Wafi-Golpu Project		
File Name: 0520DD_23_F01.02_GIS			

Source:
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Roads and watercourses from NSO.
Imagery from ArcGIS Online (capture date unknown) and WGJV (capture date 2016).

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Date: 26.04.2018
Project: 754-ENAUABTF100520DD
File Name: 0520DD_23_F01.03_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Proposed coastal infrastructure

Figure No: 1.3

1.1 HHRA study area

The human health risk assessment (HHRA) is intended to identify contaminants that may be released to the environment as a result of the Project's activities and addresses:

- Existing (baseline) risks to the health of human receptors.
- Potential health risks associated with the proposed Project activities.

The HHRA draws upon the baseline and impact assessments conducted for the Project EIS that relate to human receptors. The study areas of concern for the HHRA are defined as the areas that could be directly or indirectly impacted by contaminants as a result of Project construction and operations activities. A qualitative discussion related to closure activities is also presented in Section 6.2.3.

The areas of interest include those in and surrounding the Project disturbance footprint. However, the focus mainly extends beyond this to identify potential receptors that may be exposed as a result of contaminant migration to downstream or downgradient aquatic environments.

The Socioeconomic Baseline (Coffey, 2018c) identified study areas defined to characterise which groups of people, and in which locations, may potentially be subject to particular types of impact associated with the Project. The study areas were defined via consideration of a village location in relation to the Project footprint (and in the case of Lae, the location of the city), the type of Project activity that may occur in proximity to communities and the direct or indirect (induced) effect which development of the Project might have upon these villages.

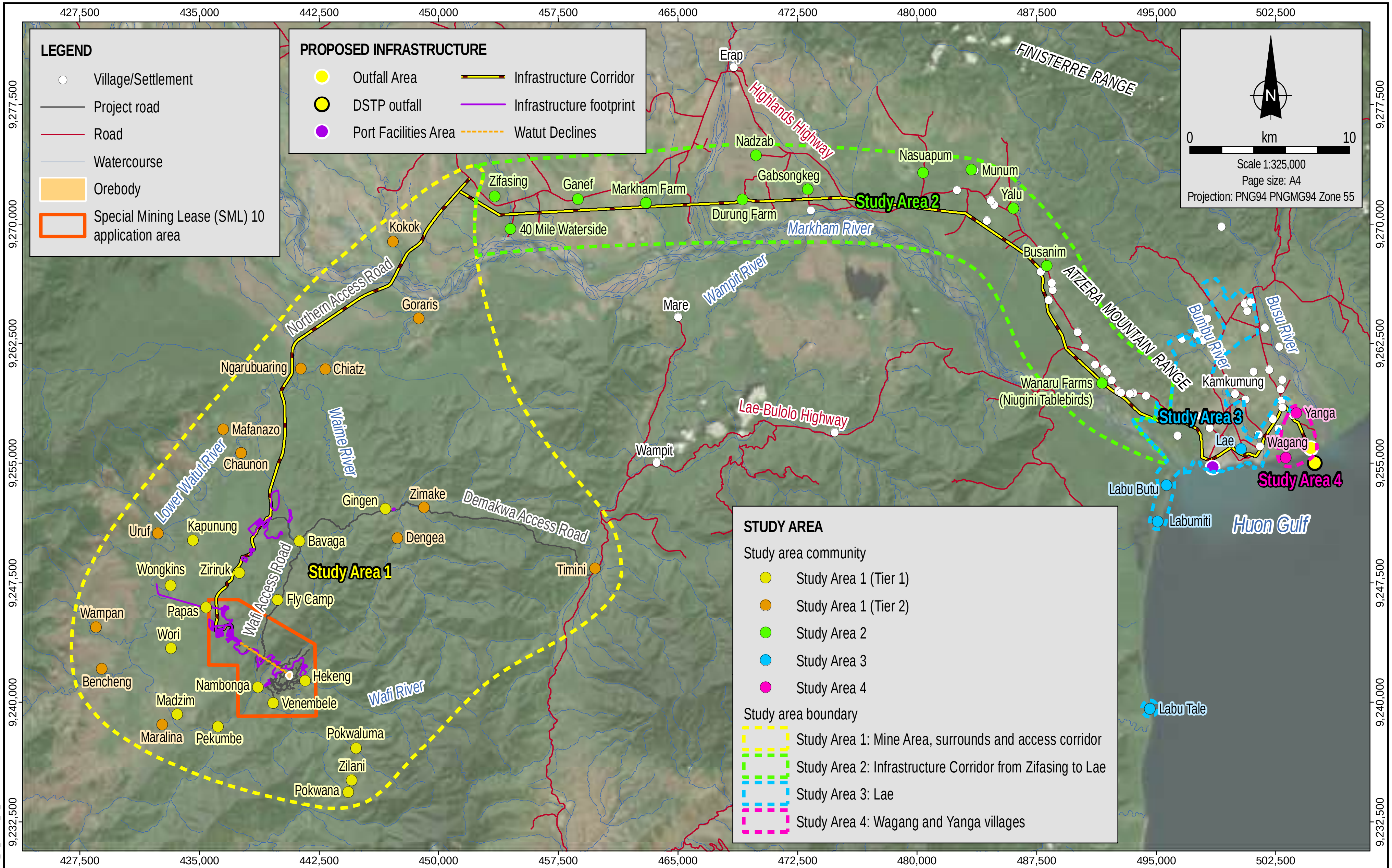
The four study areas adopted for the Socioeconomic Baseline (Coffey, 2018c) have subsequently been adopted for the HHRA as follows, with the addition of villages Labu Butu, Labumiti and Labu Tale, located near the Labu Lakes, into Study Area 3. This addition was made as the existing baseline data for these villages was considered representative of other coastal villages where limited data was available, and therefore useful to informing the HHRA baseline assessment. The study areas are shown in Figure 1.4 and are referred to as:

- Study Area 1: Villages within the Mine Area surrounds.
- Study Area 2: Villages within the Infrastructure Corridor from Zifasing to Lae.
- Study Area 3: Lae and Labu villages.
- Study Area 4: Wagang and Yanga villages.

1.2 Relevant studies

The Wafi-Golpu Project Feasibility Study Update (Coffey, 2018d) finalised in 2018 was informed by numerous studies, of which the following are relevant to the preparation of the HHRA:

- Morobe Mining Joint Ventures Public Health and Biomedical Survey Report prepared by Abt JTA (2013).
- Wafi-Golpu Project EIS – Baseline Surface Water and Aquatic Ecology Report - Mine Area to Markham River. Prepared for WGJV by BMT WBM. August 2017. BMT WBM (2018a).
- Wafi-Golpu Project EIS – Catchment and Receiving Water Quality Modelling. Prepared for WGJV by BMT WBM. February 2018. BWT WBM (2018b).
- Wafi-Golpu Project - Nearshore marine characterisation study. Prepared by Coffey Environments Australia Pty Ltd. (2018a).
- Wafi-Golpu Project - Deep-slope and pelagic fish characterisation study. Prepared by Coffey Environments Australia Pty Ltd and Marscco. (2018b).
- Socioeconomic Baseline - Wafi-Golpu Project. Prepared by Coffey Environments Australia Pty Ltd. (2018c).



Source:
Study areas from Coffey
SML and orebody from WGJV.
Villages, infrastructure and project roads from WGJV and Coffey.
Roads and watercourses from NSO.
Imagery from ArcGIS Online (capture date unknown).

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Date: 26.04.2018
Project: 754-ENAUABTF100520DD
File Name: 0520DD_23_F01.04_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

HHRA study areas

Figure No: 1.4

MXD Reference: 0520DD_23_GIS007_v0_4

- Wafi-Golpu Project: Air Quality and Greenhouse Gas Impact Assessment. Report prepared by SLR Consulting Australia Pty Ltd. SLR. (2018).
- Assessment of Metal Bioaccumulation and Biomagnification from DSTP in the Huon Gulf. Report prepared for Coffey Environments Australia Pty Ltd by Tetra Tech, Inc. (2018a).

1.3 Legislative requirements

PNG legislation does not explicitly stipulate that socioeconomic elements are to be addressed as part of Project development; however socioeconomic aspects are included in PNG guidelines for development of an EIS and their inclusion is considered good practice as part of project development. The *Mining Act 1992* and the *Environment Act 2000* create a framework that requires a mining lease applicant to adequately provide for the protection of the environment, which by definition includes people and communities.

1.3.1 Environment Act 2000

The Environment Act is the principal legislation for regulating the socioeconomic and environmental effects of projects in PNG. The Act aims to promote sustainable development by minimising negative impacts of projects to the environment and people of PNG. This aim is achieved primarily by requiring project proponents to obtain authorisation (an environment permit) before undertaking activities that may cause environmental harm. This permit and the special mining lease must both be granted before work can commence.

The Act's definition of 'environment' highlights social and cultural values as matters of importance. In Section 2 the Act defines the environment as:

> *(a) ecosystems and their constituent parts including people and communities and including human-made or modified structures and areas; and*
>
> *(b) all natural and physical resources; and*
>
> *(c) amenity values; and*
>
> *(d) the qualities and characteristics of locations, places and areas, however large or small, that contribute to their biological diversity and integrity, intrinsic or attributed scientific value or interest, amenity, harmony and sense of community; and*
>
> *(e) the social, economic, aesthetic and cultural conditions which affect the matters stated in [the above] paragraphs of this definition or which are affected by those matters.*

The importance attached to social and environmental values in PNG is highlighted in Section 5 of the Environment Act, which states:

> *All persons exercising powers and functions under this Act shall recognise and provide for the following matters of national importance:*
>
> *(a) The preservation of PNG traditional social structures; and*
>
> *(b) The maintenance of sources of clean water and subsistence food sources to enable those Papua New Guineans who depend upon them to maintain their traditional lifestyles; and*
>
> *(c) The protection of areas of significant biological diversity and the habitats of rare, unique or endangered species; and*
>
> *(d) The recognition of the role of land-owners in decision-making about the development of the resources on their land; and*
>
> *(e) Responsible and sustainable economic development.*

1.3.2 Guidelines for completing an EIS (including the HHRA)

Information guidelines prepared by the Department of Environment and Conservation (now Conservation and Environment Protection Authority (CEPA)) states that the EIS must document all environmental and social issues and indicate commitments to the employment of relevant mitigation measures in relation to the development activity (DEC, 2004b, p.1). The guideline also states that the EIS should include:

- A description of the proposed development activity.
- The development timetable.
- Characteristics of the receiving environment, including the social structure and socioeconomic data on the resource/land owners, LLG, the Province and PNG as a whole, and which may include:
  - Demographic information.
  - Information on existing infrastructure.
  - Information on public health issues (if applicable).
  - Information on present economic status of the Project Area.
  - Description of existing social services.
  - Details of archaeological, historical, cultural or religious features of the Project Area under consideration.
- Environmental management, monitoring and reporting, including information on a socioeconomic management and monitoring strategy (DEC, 2004b, pp.2-4).

The guideline also recommends that environmental management, monitoring and reporting requirements are separated during the various stages of the development (DEC, 2004b, p.4).

2 Objectives

Specific objectives of the HHRA are to:

- Develop a detailed conceptual site model to understand and describe potential Project-related contaminant source(s) and the fate and transport pathways for each contaminant of potential concern (COPC). Identify receptors (such as villages) that may be impacted by contaminants released to the environment.
- Determine the COPCs, based on compounds potentially released as a result of Project activities and their known toxicities to human health. A screening evaluation using available baseline data, in addition to modelling outcomes of potential future migration in water and/or air that may result in harmful exposures to human receptors, will further refine the number of COPCs.
- Describe and assess the exposure pathways for human receptors. Estimate the potential chronic intakes associated with baseline conditions and with Project activities, in conjunction with the potential toxicological effects to estimate potential exposures.
- Evaluate risks (quantitatively or qualitatively as appropriate) and provide recommendations for further investigations and/or management strategies where potentially elevated risks are identified.

The HHRA addresses potential health risks to receptor populations downstream of Project areas, and in the vicinity of Project related infrastructure. Potential exposures to WGJV employees and contractors in the Mine Area, Infrastructure Corridor and Outfall Area during construction, operation and closure phases are not evaluated in this assessment as occupational exposures are assumed to be managed by the mine operator. The evaluation of potential impacts of Project activities on lifestyle-related illnesses will be addressed in the Socioeconomic Impact Assessment (Chapter 18 of the EIS (WGJV, 2018)).

3 Structure of the HHRA

3.1 Definition of Tier in this report

The terms Tier 1 and Tier 2, as presented in this report, relate to the location of particular villages within Study Area 1, as defined in the Socioeconomic Baseline (Coffey, 2018c), and also to a staged approached commonly used in the risk assessment process. In order to avoid confusion, the study area tiers have been presented as Study Area (Tier 1), and the tiered process used in the HHRA approach has been defined and referenced as follows:

- Tier 1 (T1):
  - A Tier 1 screening evaluation is a risk-based analysis comparing site data with generic published screening criteria for a particular receptor population and media (for example, drinking water for a villager). This tier has the lowest data requirement, generic exposure assumptions, and applies the most conservative criteria.
- Tier 2 (T2):
  - A Tier 2 health risk evaluation is a more detailed site-specific assessment in which risks to potentially exposed populations are assessed using site-specific data on pathways, land uses and the characteristics of the exposed populations. A Tier 2 evaluation usually involves the use of a quantitative exposure model. A Tier 2 evaluation is more complex than a Tier 1 evaluation and requires more site-specific information. As a result, a health protective effect will be achieved with a lower level of conservatism.

3.2 Report structure

The HHRA has been structured as follows:

- Introduction (Chapter 1).
- Objectives (Chapter 2).
- Structure of the HHRA (Chapter 3).
- Risk assessment methodology (Chapter 4).
- Proposed Project and issue identification (Chapter 5):
  - Describes the environmental setting, the receiving environments and the villages that are found in these locations.
  - Provides an overview of the village settings in each Study Area.
  - Provides a general description of the proposed Mine Area and activities. Includes discussion of the modelling outcomes of potential releases resulting from Project activities. The proposed DSTP is discussed briefly with greater detail provided in Chapter 12.
  - Discussion of proposed management measures that were assumed to minimise the release of contaminants to the environment during construction and operation phases.
- Conceptual Site Model (CSM) (Chapter 6):
  - Reviews the source, transport pathway, receptor and exposure route linkages as all four of the steps must be present for a complete exposure pathway to exist. The selection of exposure pathways requiring further evaluation is based on the proposed Project information (Chapter 5) regarding contaminant sources, transport pathways and receptor and exposure routes (Chapter 6).
- Exposure evaluation Tier 1 (T1) baseline screening assessment (Chapter 7):
  - Presents the screening criteria selected to conduct a Tier 1 (T1) screening assessment of the baseline data.
  - Provides information regarding when and where baseline investigations were undertaken, the types of sampling undertaken and references to the reports detailing methodology and results.
  - Summarises the baseline data for air, soil, sediment, fresh and marine waters and fresh and marine biota (Chapter 7).

  - Presents a qualitative Tier 1 (T1) evaluation of baseline conditions for human receptors. Media sampled in the baseline investigations are compared to screening criteria to determine which COPCs and exposure pathways required more detailed evaluation.
- Tier 2 (T2) human health risk assessment (Chapter 8 to Chapter 11):
  - Provides a quantitative Tier 2 (T2) health risk assessment of the baseline conditions. Chapter 8 refines the selection of potential exposure pathways, contaminants and relevant exposure inputs and assumptions needed to quantify daily intakes. Includes qualitative evaluation of modelled air impacts to human health
  - The assessment of contaminant toxicity is undertaken in Chapter 9 and the calculation of risks is characterised in Chapter 10. Includes evaluation of the uncertainties inherent in any risk assessment and a semi quantitative evaluation of the parameters and assumptions adopted in this report (Chapter 11).
- Health risks associated with proposed DSTP (Chapter 12):
  - Provides a detailed description of the DSTP system, tailings composition and potential impacts to the food chain and health of the coastal villagers. Includes background information on coastal village lifestyles, diets and fishing behaviours.
  - Presents a literature review of health studies relating to DSTP projects in other locations.
- Potential risks to human receptors, further investigations to refine the risk inputs, and management of identified risks if identified (Chapter 13).

4 Risk assessment methodology

On the basis that PNG currently has not developed a risk assessment methodology or stipulated relevant international guidance, the human health risk assessment methodology was conducted in accordance with the Australian 'National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013' (NEPC, 2013), referred to herein as the NEPM. The specific provisions within the NEPM are:

- Guideline on Site-Specific Health Risk Assessment Methodology, Schedule B4.
- Guideline on Derivation Health-Based Investigation Levels, Schedule B7.

The risk assessment approach provided in the NEPM is consistent with international guidance published by environmental agencies such as:

- World Health Organization (WHO).
- United States Environment Protection Agency (USEPA).
- United Kingdom Environment Agency (EA).
- Canadian Council of Ministries for the Environment (CCME).

Additional international resources have been used as appropriate where information is not available in the NEPM 2013 or agencies listed above and may include referenced documents from these and the following sources:

- State of PNG Public Health (Drinking Water) Regulation 1984Joint Expert Committee on Food Additives (JECFA): Food and Agriculture Organization (FAO)/World Health Organization (WHO).
- Food Standards Australia New Zealand (FSANZ).
- Environmental Health Standing Committee (enHealth, 2012a and enHealth, 2012b).
- Risk Assessment Information System (RAIS, 2007).
- Village or PGN specific inputs were adopted wherever available. Exposure and modelling inputs used in the HHRA, specific to PNG, were sourced from:
  - Centre for Environmental Health Pty Ltd (CEH).
  - Specialist studies undertaken for the Wafi-Golpu Joint Venture (WGJV).

The risk assessment process conducted as part of this HHRA comprises issue identification, data evaluation, toxicity assessment, exposure assessment and risk characterisation. The conceptual site model was generated early in the process and was constantly refined as more data was collected. Evaluation of uncertainty is part of each stage of works and ensures realistic information is provided in the assessment and the findings of this HHRA can be utilised as part of the risk management or risk communication processes as required.

The methodology adopted is summarised in Figure 4.1.

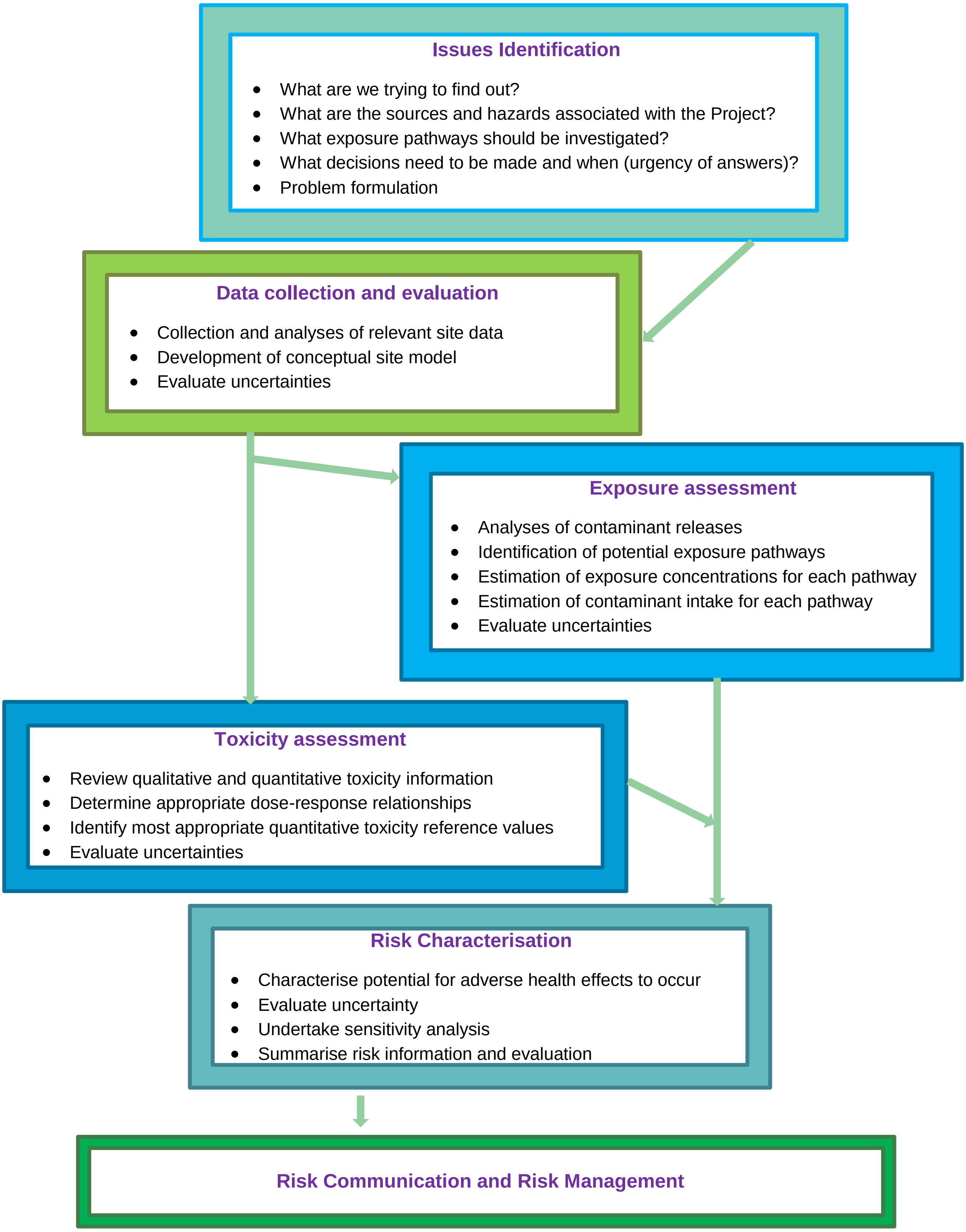


Figure 4.1: Risk Assessment Process (Adapted from NEPM, 2013)

5 Proposed Project

This chapter presents the Project environmental and social settings and an overview of the Project description. The proposed Project infrastructure locations and associated activities will determine where contaminants are potentially released to the environment, and the environmental setting will influence whether receptors in the various Study Areas may potentially be exposed as a result.

5.1 Environmental setting

The Project Area is located approximately 300km north-northwest of Port Moresby, and the Mine Area is 65km southwest of Lae, within the foothills of the Watut River catchment. The northeastern coast of PNG experiences two distinct seasons; a southeast monsoon, from mid-May to October, and a northwest monsoon, from mid-November to the end of March, with intervening periods of light, variable winds. The Mine Area is also characterised by low wind speeds, high humidity and warm temperatures (average maximum of 28 degrees Celsius (°C) and average minimum of 21°C). The Mine Area has an average annual rainfall of 2,836mm.

Groundwater recharge is a direct function of rainfall infiltration with some variation to local groundwater recharge rates expected as a result of differences in altitude, soil cover and slope. In the Mine Area, high recharge rates to groundwater have been calculated from river flow levels and given the occurrence of rainfall throughout the year, recharge to the groundwater system should occur over the entire year. Regional groundwater discharge within the Mine Area is expected to be to the Wafi River and Nambonga Creek which drain the slopes of Mt Golpu.

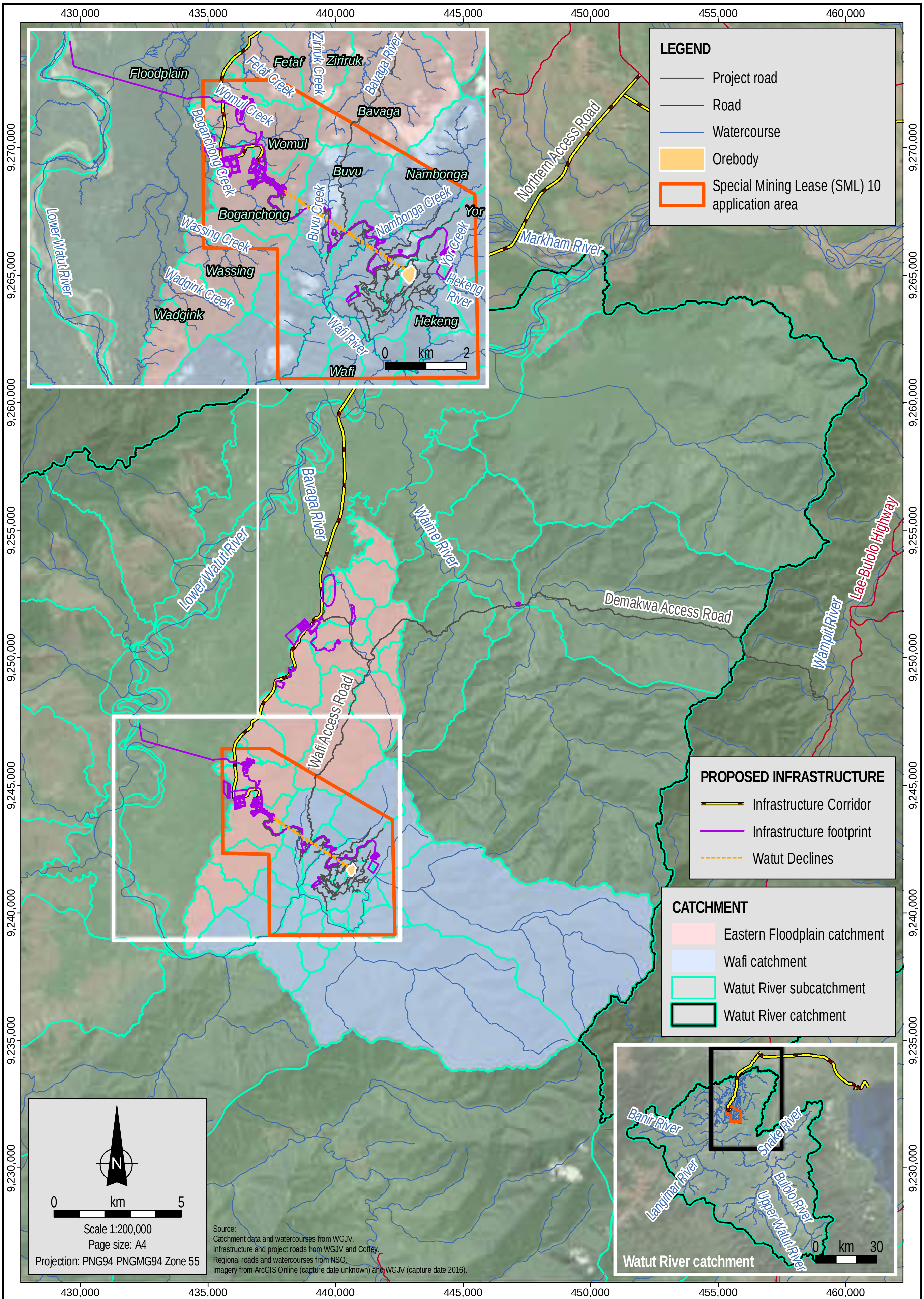
The Project Area abuts the Huon Gulf, into which a number of large rivers (Markham, Bumbu and Busu amongst others) discharge. The seafloor of the northwest Huon Gulf is a highly dynamic environment driven by the regional terrestrial topography, high rainfall and regional tectonic setting. Together, these result in large amounts of sediments eroded from the land associated with the river catchments, being delivered into the Huon Gulf and transported to great depth in a well-defined submarine canyon known as the Markham Canyon. The canyon broadens with distance offshore, eventually becoming part of the New Britain Trench. The canyon reaches depths in excess of 9,000m.

The Markham Canyon receives approximately 60Mt/a of terrestrial sediment from several large rivers along the northern coast of the Huon Gulf, primarily the Markham and Busu. The sediment entering the gulf results in the formation of prominent turbid sediment plumes on the surface and extensive bottom-attached sediment transport and mass movements (landslides) traveling down the canyon.

5.1.1 Freshwater environment

The key focus of the freshwater environment characterisation is on watercourses in the Mine Area located in the Lower Watut River catchment (i.e., from the Wafi River catchments to the Markham-Watut river confluence), which is commensurate with the scale and duration of Project activity proposed in this area.

The Mine Area and a portion of the Infrastructure Corridor will extend across several sub-catchments and features of the Lower Watut River catchment (Figure 5.1). The main catchments and associated watercourses are presented in Table 5.1.



coffey A TETRA TECH COMPANY	Date: 26.04.2018 Project: 754-ENAUABTF100520DD File Name: 0520DD_23_F05.01_GIS	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Catchments and streams in the Mine Area and Infrastructure Corridor	Figure No: 5.1

Table 5.1: Lower Watut River catchments overview

Catchment	Sub-catchment
Watut upstream of the Lower Watut River and Wafi River (total area: 4,161 km^2)	Upper Watut
	Bulolo
	Snake
	Langimar
	Banir
Wafi River (approximate area: 120 km^2)	Upper Wafi / Hekeng
	Hekeng Creek
	Zamen
	Nambonga/ Buvu
Eastern floodplain catchments and floodplain creeks, including Bavaga River	Bavaga
	Bobul Catchment area includes Ziriruk Creek and upper Bobul (Finchif and Kufikasep Creeks)
	Mari Catchment area include Wassing and Wadgink Creeks
	Boganchong
	Womul
	Chaunong Catchment area includes Bobul, Mari, Boganchong and Womul Creeks.

5.1.1.1 Lower Watut River (main channel) catchment

The Watut River catchment contains five main river systems, namely Bulolo, Snake, Langimar and Banir rivers, and the main arm of the Watut River. Other tributaries draining into the Watut River include the Waime, Isimp/Langimar, Mumena, Wafi and Laloona rivers. The Watut River drains the catchment in a generally northern direction to its confluence with the Markham River.

The Lower Watut River is a large, slow flowing and turbid section of the Watut River that bisects a broad floodplain. It drains an area of approximately 4,161km^2 upstream of the confluence with the Wafi River. Within the low-lying floodplain area, a number of catchments drain to the river, including the small, steep catchments to the eastern side of the floodplain which are 1km^2 to 5km^2 in area and prone to flash flooding.

The morphology of the Lower Watut River is highly dynamic and has changed considerably over time.

5.1.1.2 Wafi River catchment

The Wafi River catchment is located in the middle section of the Watut River basin. The catchment comprises mountainous terrain (elevation of 760m at Mt Golpu) with deeply incised valleys and steep valley walls of up to 45º and is largely forested. Streams in the Wafi River catchment are fast-flowing with rocky substrates and largely intact riparian vegetation. The main tributaries of the Wafi River are Yor Creek, Hekeng River (upper Wafi River), Zamen River, Buvu Creek and Nambonga Creek.

Streams are shallow and narrow, but widen and deepen in the middle and lower parts of the Wafi River valley. The tributaries of the Wafi River are predominantly fed by overland flows originating in their steep catchment areas; however, there is also an unquantified contribution to both major and minor tributaries from groundwater.

5.1.1.3 Eastern floodplain catchments and floodplain streams

The Lower Watut River floodplain area has numerous small streams draining the steep catchments to the west and east. Some sub-catchments to the east of the floodplain fall within the Mine Area and Infrastructure Corridor, and these include the Bavaga River and Bobul, Kufikasep, Finchif, Ziriruk, Fetaf, Womul, Boganchong, Wassing and Wadgink creeks as shown in Figure 5.1.

The floodplain streams receive inflows from the catchment areas to the east of the floodplain and are also likely to receive flows originating from groundwater within the floodplain, wetland areas within the floodplain, and the Lower Watut River during times of flood. There is currently only a limited understanding of the groundwater and surface water interaction in the floodplain.

Key Project activities include the in-stream construction of the Watut Declines Portal Terrace and Watut Waste Rock Dump within Boganchong Creek, including construction of the raw water dam and sedimentation pond, which will lead to altered flow regimes in this creek. Construction of the Northern Access Road will also impact numerous watercourses that drain the eastern sub-catchments of the Lower Watut River floodplain.

5.1.2 Marine environment

The marine environment likely to be affected by Project activities primarily includes the nearshore areas of the Huon Gulf near Lae in the vicinity of the Port Facilities Area and the Outfall Area, and the pelagic and benthic habitats potentially impacted by subsurface tailings plumes, tailings deposition, and tailings resuspension (resulting from periodic seafloor mass movement events), which have been modelled in Tetra Tech (2018b). Tailings are predicted to mainly affect the seafloor environment near the Outfall Area, along the coast near the Busu River, and flow downslope along the walls and floor of the Markham Canyon.

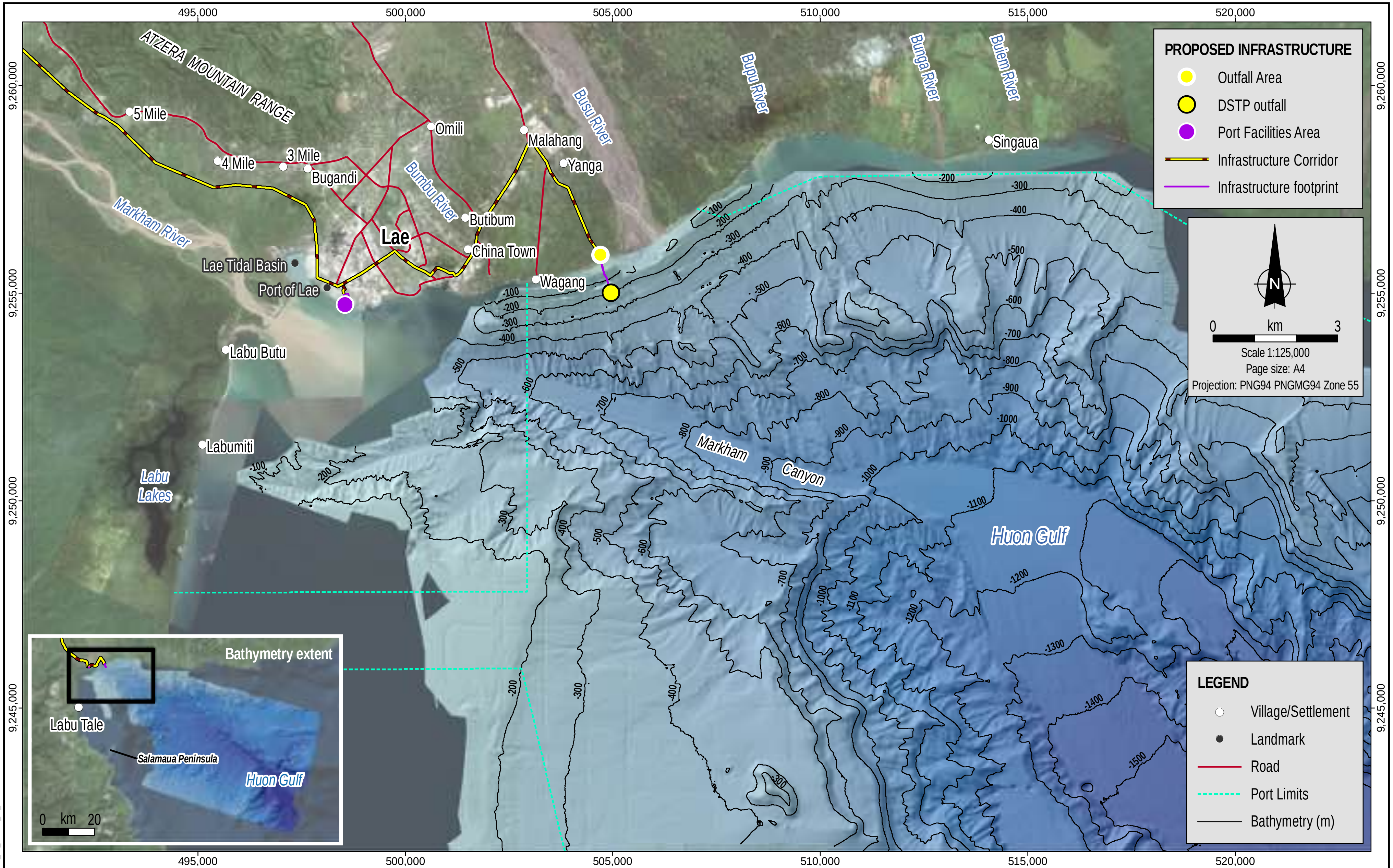
Sediments associated with the discharging rivers (Markham, Bumbu and Busu rivers) in this area of the Huon Gulf north coast influence nearshore marine conditions. The combination of steep mountainous catchments in the upstream areas of the river and high rainfall contribute to relatively large flows with high concentrations of suspended sediment. Sediment plumes generally extend several kilometres from their discharge locations into the Huon Gulf and are a major factor limiting the growth of seagrass and the development of coral reefs in the region. The large terrigenous sediment plumes are transported to great depths in the well-defined submarine canyon known as the Markham Canyon (Figure 5.2). The canyon broadens with distance off-shore and sediment movements such as landslides cause significant movement of sediment mass to travel down the canyon.

The Busu River is the primary source of sediment input into the vicinity of the Coastal Area, apart from the Markham River. The Bumbu River drains industrialised areas of Lae and transports rubbish and urban runoff into the Huon Gulf. Several small coastal lagoons exist between Lae and the Busu River, and these are commonly used for swimming and bathing by local people.

To the south of Lae, the Huon Gulf comprises a complex coastline punctuated by braided rivers and multiple channels, backed by steep mountains up to 2,700m high. Immediately south of the Markham River mouth, the coast is low-lying and dominated by swamp over a distance of approximately 10km. This area includes the dense mangrove forest and tidal channels of the Labu Lakes.

The nearshore marine ecology within several kilometres of Lae and the Outfall System contains sparse benthic flora and fauna. This is due to the high terrestrial sediment input, low light penetration and episodic high freshwater inflow. In addition, the occasional occurrence of seafloor sediment slumps associated with the steeply sloping seafloor for much of the Huon Gulf north coast between the Markham and Busu rivers confirms the environment is not conducive to supporting a thriving benthic community in this area.

No live coral reefs or seagrass beds were observed during field studies in 2016 and 2017 aside from coral reefs that were present at Busama and Salamaua, which is at the closest some 20km from the Outfall Area, on the Huon Gulf south coast.



Source:
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Roads and Port Limits from Coffey (Port Limits indicative only).
Bathymetry from WGJV survey.
Imagery from WGJV (capture date 2016) and ArcGIS Online (capture date unknown).

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WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Coastal area - Markham Canyon, Huon Gulf

Figure No: 5.2

MXD Reference: 0520DD_23_GIS006_v0_3

5.2 Social setting

This section presents a high-level overview of the Project's social setting. A more detailed description of the social setting specific to each of the four study areas is presented in Section 6.4 of this report.

Villages in and around the Mine Area, within Study Area 1, are inhabited by the Babuaf, Hengambu and Yanta people, while villages on the Lower Watut and Markham rivers (in the vicinity of the proposed Infrastructure Corridor – Mine Area to Zifasing section) are generally occupied by the Wampar people. Land remains in customary ownership, although there are disputes over land ownership boundaries in some places. The population of the Babuaf, Hengambu and Yanta villages is approximately 3,900. A further 6,000 people live in surrounding villages that are located: (1) along the existing Demakwa Access Road; (2) in the vicinity of the Infrastructure Corridor between the Mine Area and Zifasing; and (3) on the west bank of the Watut River, to the north of its confluence with the Wafi River. Other than villages along the Demakwa Access Road, most villages south of Zifasing have no road access.

Subsistence agriculture is the dominant lifestyle across the majority of Study Area 1, supplemented by hunting, fishing and some cash cropping. Villagers are generally dependent on the natural environment for food, housing materials, firewood and medicine, which are either grown in gardens or gathered from the surrounding forests. This is due, in part, to the terrain and lack of access to electricity and transport, which limits the ability to participate in more commercially-oriented activities.

Study Area 2 includes villages that may be impacted as a result of the proposed Infrastructure Corridor. As the Infrastructure Corridor nears the village of Zifasing and turns east towards Yalu, it passes several Wampar villages, including Ganef, Gabsonkeg, Nasuaupum and Munum, as well as agricultural enterprises, notably chicken farms and palm oil plantations. Between the settlement of Yalu and the Port Facilities Area, where the concentrate and fuel pipelines will terminate, communities are situated in a peri-urban setting along the Highlands Highway.

Residential settlement becomes markedly denser in the approach to Lae and Study Area 3. While there are some forested and grassed areas, Lae is a major transport hub and commercial, administrative, industrial and educational centre for both the Morobe Province and PNG and land use is increasingly dominated by industrial and commercial development. The Port Facilities Area is located within the gazetted area of the Port of Lae. The Labu villages are located to the south of the Markham River mouth, opposite Lae. The terrestrial components of the Outfall System are located within customary land of the Wagang and Yanga villages in Study Area 4.

The activities, resources and baseline conditions for receptors in each of the Study Areas are described in greater detail in Section 6.4.

5.3 Summary of Project description

The WGJV Participants are currently investigating the feasibility of constructing, operating and (ultimately) closing the Wafi-Golpu Project (the Project) as described in the Wafi-Golpu Project EIS Chapter 6, Project Description (WGJV, 2018).

Development of the Project will require significant infrastructure and facilities to operate. The principal components of the Project include:

- Underground mine comprising three block caves: Block Cave (BC) 44, BC 42 and BC 40, to be developed in stages and located beneath Mt Golpu at Reduced Level meters (mRL) 4,400mRL, 4,200mRL and 4,000mRL, respectively. Primary access to the orebody will be obtained via 4.6km-long twin declines (tunnels). Initial access to undertake further geotechnical data collection will be established via the Nambonga Decline (Figure 5.3).
- Ore processing and concentrate transport/handling facilities, including a pipeline to transport concentrate slurry from the Mine Area to the Port Facilities Area at the Port of Lae (Figure 5.4).

- A deep sea tailings placement (DSTP) system for tailings management into the Markham Canyon in the Huon Gulf near Lae (Figure 5.5), with tailings transported by pipeline from the Mine Area to the Outfall Area on the Huon Gulf coast.
- On-site power generation facilities located within the Mine Area, with intermediate fuel oil delivered via pipeline from the Port Facilities Area or a third-party supplier located adjacent to the Port of Lae.
- Waste rock dumps to store non-acid forming (NAF) and potentially acid-forming (PAF) rock generated during the development of the declines and ventilation shaft.
- Water and waste management facilities, including water treatment facilities, wastewater discharge and raw water make-up pipelines and raw water and sedimentation dams. During construction, treated wastewater (mine water and sewage effluent) will be discharged via a pipeline to the Watut River with the outlet located adjacent to Wongkins Village as shown in Figure 1.2.

A summary of anticipated Project infrastructure and Facilities according to geographic area (Mine Area, Infrastructure Corridor and Coastal Area) is presented in Appendix C. Further detail on key infrastructure in the Mine Area is summarised below.

The Mine Area includes land which is steep, mountainous and covered by dense tropical rainforest (to the east), transitioning to the broad, flat to gently undulating Lower Watut River valley and floodplains (to the west).

Watut Declines Portal Terrace

The Watut Declines Portal Terrace high wall will form a geotechnically-stable, steeply-angled face from which to commence construction of the entrances to the twin declines (the portals) to access the Golpu ore body via the proposed block cave mine. The portal terrace, high wall and proposed facilities are presented in Figure 5.6. The Watut Declines Portal Terrace will be built on the side of the Boganchong Creek valley to form a marshalling area for the underground activities. During caving operations, ore from the block cave will be crushed underground and then conveyed to the surface to the Portal Terrace. The crushed ore will be continued to be conveyed to a coarse ore stockpile located adjacent to the Watut Process Plant.

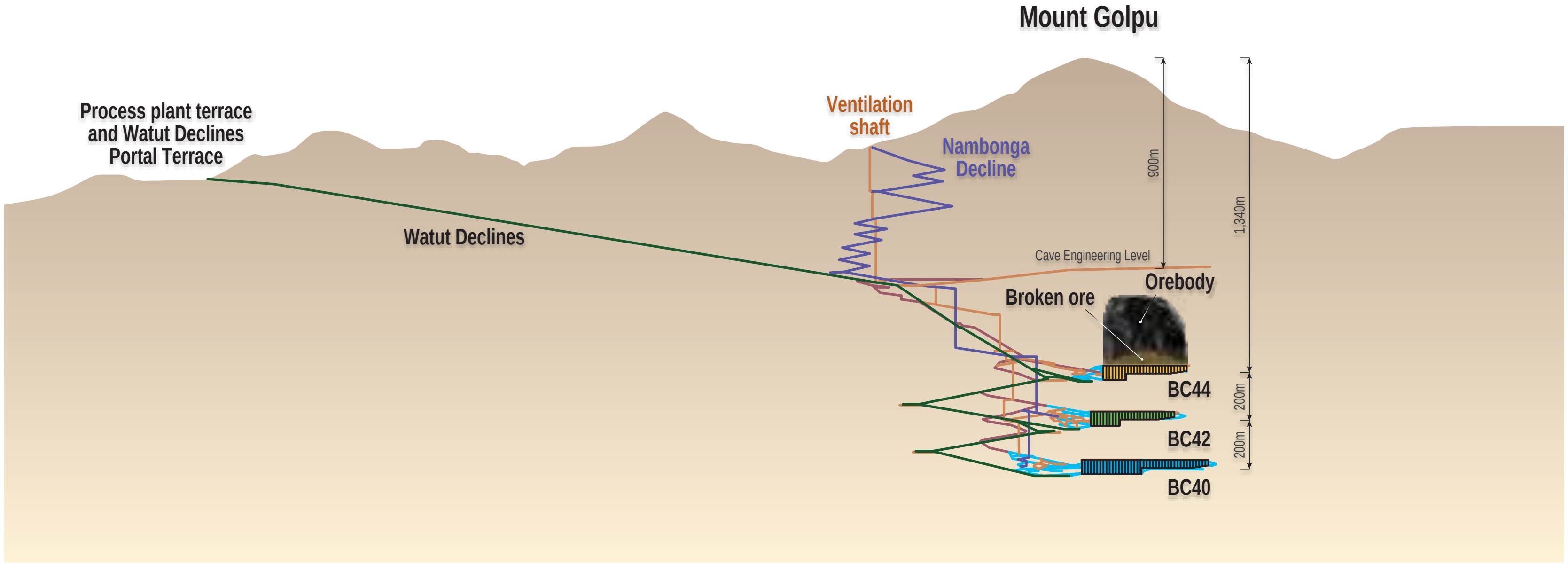
Watut Process Plant

Crushed ore will be processed and treated on the process plant terrace. A temporary ore stockpile is planned to store ore extracted during the development of the block cave extraction levels. The stockpile will be located on a purpose-built compacted earth base constructed between the Watut Declines Portal Terrace and the process plant terrace. The general arrangement of the process plant terrace is shown in Figure 5.7.

5.4 Proposed management measures to address release of contaminants

Management measures to address potential releases of contaminants to the environment are proposed for the construction and operation of the Project. These proposed measures are noted in this report as their implementation is assumed to minimise and manage potential releases of contaminants to the environment that would otherwise be evaluated in this HHRA to assess the associated potential health risks.

In order to develop the conceptual site model and determine potential exposure pathways (refer to Chapter 6) the successful implementation of the Project Environmental Management Plan (EIS Attachment 3) has been assumed. Key proposed management measures for the HHRA assumed to be implemented as part of the Project Environmental Management Plan are listed in Appendix F.



Source:
Developed from WGJV: 532-1005-EN-REP-0004-1.4, Figure 4.6, Figure 4.7
with updated mine layout.

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WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Typical block caving method schematic and block caving extraction levels cross section

Figure No:
5.3

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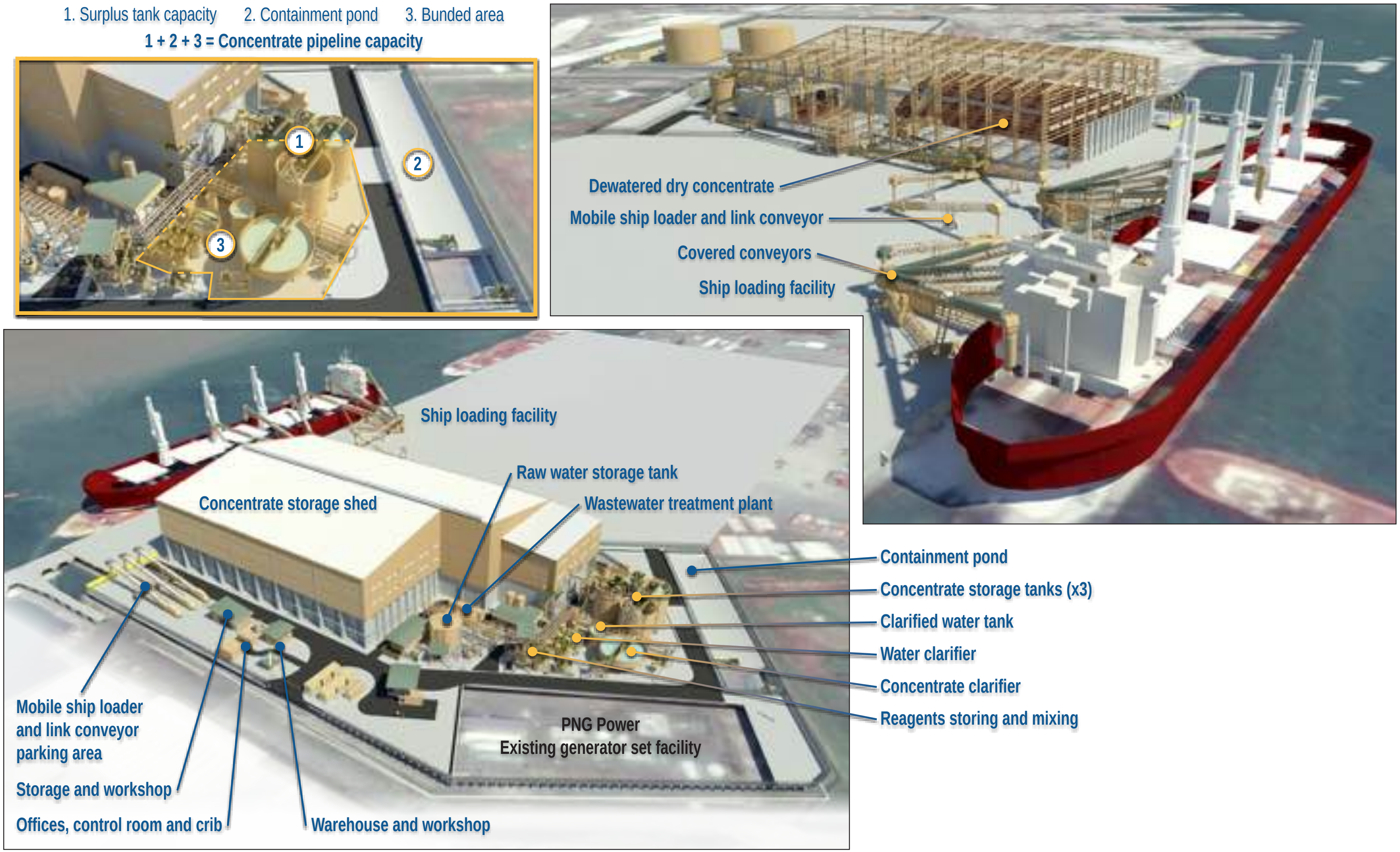

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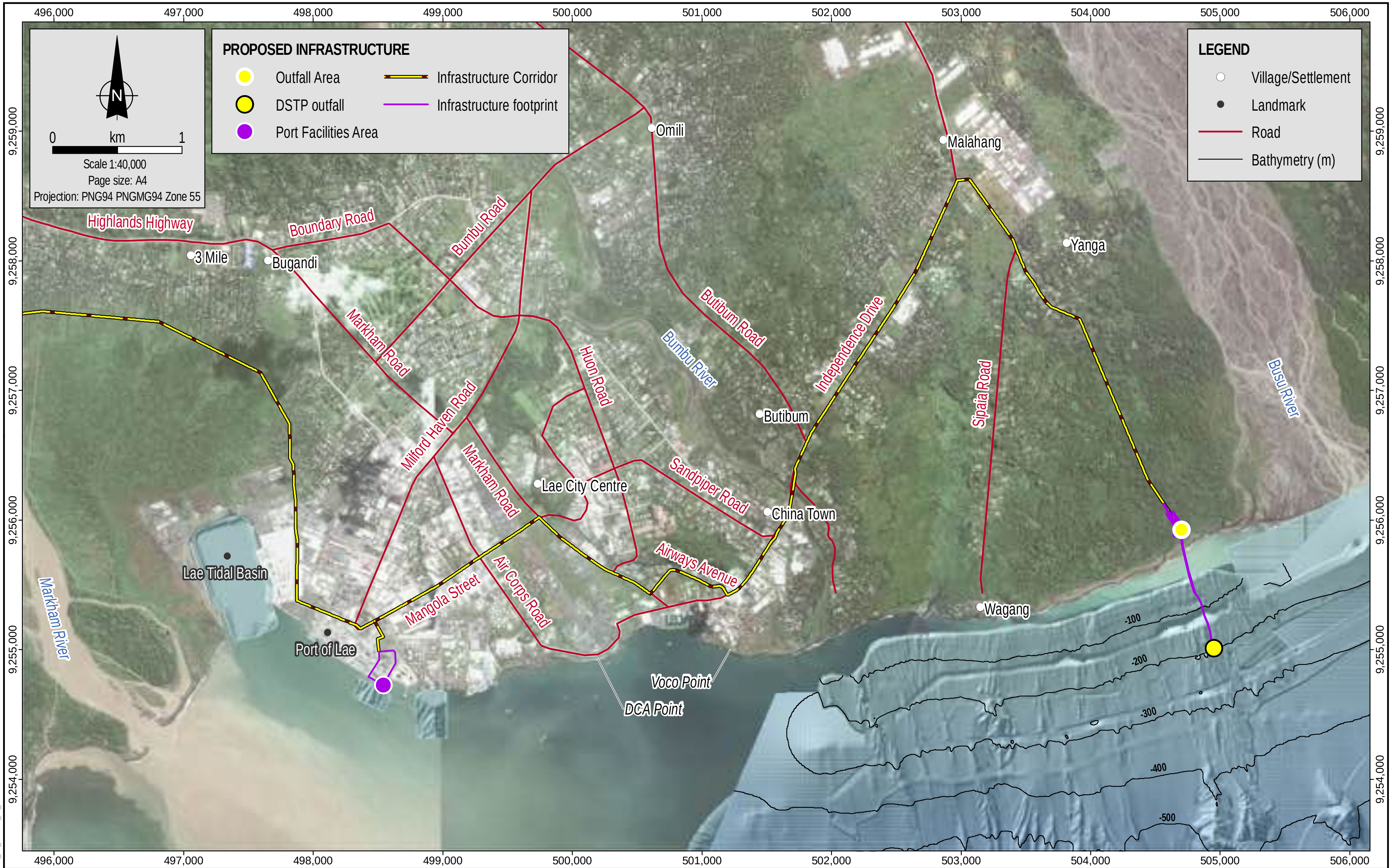
WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Port Facilities Area

Figure No: 5.4



MXD Reference: 0520DD_23_GIS004_v0_3

Source:
Villages/Settlements, landmarks and infrastructure from WGJV and Coffey.
Bathymetry from WGJV survey.
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WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Tailings outfall area

Figure No: 5.5

coffey A TETRA TECH COMPANY	Date: 26.04.2018 Project: 754-ENAUABTF100520DD File Name: 0520DD_23_F05.06_GRA	WAFI-GOLPU JOINT VENTURE Wafi-Golpu Project	Watut Declines Portal Terrace general arrangement	Figure No: 5.6

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Project: 754-ENAUABTF100520DD
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WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Process plant terrace and Watut Declines Portal Terrace infrastructure and general arrangement

Figure No: 5.7

6 Conceptual site model

The development of the conceptual site model (CSM) was critical to determining which communities may currently be exposed to contaminants as part of the baseline assessment and also as a result of the Project activities during construction and mining operations.

The CSM was applied to:

- Identify the sources of potential contaminants that may be released to the environment as a result of Project activities.
- Describe and identify those contaminants which may already be present in air, soil, surface water, sediment, groundwater and local human food sources such as aquatic biota (e.g., fish) and terrestrial biota (e.g., edible plants) based on the available baseline study data.
- Identify food biota, consistent with the EIS aquatic and terrestrial ecology assessments, taking into consideration resource use by local villagers.
- The CSM describes and presents information used to develop and understand the site setting and exposure model, including graphical representation, based on available baseline data and modelled data (air, water and sediment) and the Project description.

6.1 Exposure pathway identification

Exposure pathway identification is a four-step process involving the identification of contaminant sources, how contaminants are transported to other media and locations, and which receptors may be exposed as a result. The complete exposure route linkage process is presented in Figure 6.1.

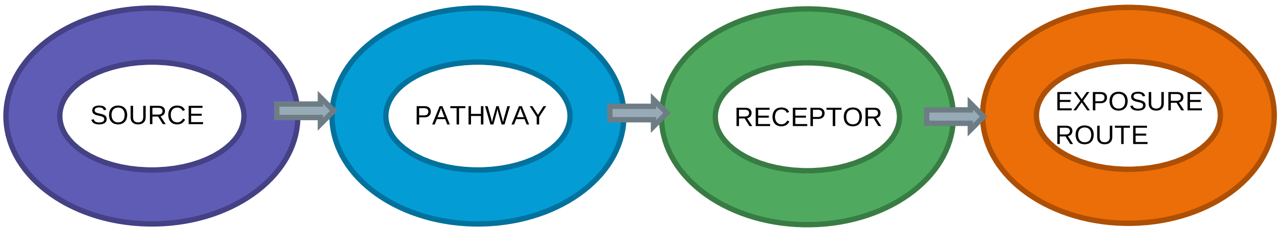


Figure 6.1: Source - Pathway – Receptor – Exposure Route Linkage Process

In order to identify which receptor groups may potentially be exposed to contaminants released to the environment as a result of the Project activities, particularly during the construction and operation phases, the contaminant sources and locations are determined based on the Project description (refer to Chapter 5). Once contaminants are released to the environment they may be transported to other media and other locations where receptors may be exposed. An example of this process would be:

- **Source**: Project Area construction, operations, processes and related activities such as mined ore brought to the surface and stockpiled.
- **Transport pathways**: The fate and transport of contaminants once released from the source. This is usually via wind, water, sediments, soil, food etc. For example, a transport pathway could be rainfall resulting in the transport of dissolved metals (leached from the ore stockpile) and fine rock particles via surface water runoff which subsequently discharges to downgradient waterways.
- **Receptors**: The point of exposure will depend on where the receptor is located. In this example, the receptors would include villagers using the water for drinking or washing, swimming or consuming aquatic biota (such as fish) that resided in the impacted downstream region of the river.
- **Exposure route**: Once the source-pathway-receptor linkages have been identified, the potential direct and indirect routes of exposures can be determined. The route of exposure describes how a contaminant enters the body either via ingestion, inhalation or dermal contact.

The following sections discuss each of the exposure pathway links:

- Contaminant sources (Section 6.2)
- Fate and transport of contaminants (Section 6.3),
- Receptor populations that may be exposed as a result of contaminant migration (Section 6.4)
- The exposure routes the selected receptors may be exposed (Section 6.5.1.2).

6.2 Contaminant source identification

The identification of contaminant sources is generally determined by the Project construction and operations activities. Aspects of the Project construction and mining process are summarised in Chapter 5. The potential release of contaminants to the environment and the mechanisms for contaminant transport is discussed to identify receptors who may be exposed as a result.

6.2.1 Air quality

6.2.1.1 Mine Area

The key Project activities that have the greatest potential for impacts on local air quality were identified as follows:

- Emissions of combustion products from the diesel generators during the construction phase and the power generation facilities during the operational phase.
- Fugitive dust emissions from the operational mining activities.
- Fugitive dust emissions from the construction of the mine site infrastructure, including declines, waste rock dumps, quarry operations and the ventilation shaft.

Dust and air emission modelling was undertaken by SLR (2018) to determine whether emissions of air pollutants would exceed the adopted health screening criteria (refer to section 7.1.1.1) at surrounding villages. The contaminants modelled included:

- Total suspended particulates; particulate matter less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$)
- The products of fossil fuel combustion; oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and carbon monoxide (CO)

Power generation facilities

Modelling of emissions from the on-site diesel generators during the construction phase estimated the predicted NO_2, SO_2 and CO concentrations were below the adopted screening criteria (refer to Section 7.1.1.1) at the surrounding villages. SLR concluded that, provided the generators are installed, operated and maintained in accordance with the manufacturer's instructions and good engineering practice, no adverse air quality impacts are anticipated as a result of these emissions.

Modelling of emissions from the proposed power generation facilities during the operational phase showed that predicted CO and NO_2 concentrations will be below the relevant screening criteria at all surrounding sensitive receptors. The predicted emissions during power generation use of intermediate fuel oil during the operation phase may exceed the SO_2 screening criteria at two locations, Ziriruk and Fly Camp. The modelling outcomes indicate villagers at these locations are potentially exposed to elevated levels of SO_2 for chronic exposure period during the operation phase of the mine and when the power plant is operating near maximum capacity, which is estimated to happen from year 16 of operations onwards.

Dust emissions

Air modelling of fugitive dust emissions was undertaken by SLR to estimate emissions of particulate matter during construction phase activities and a worst case operational scenario assuming highest production throughput.

The modelling reported the major sources of PM_{10} emissions, contributing approximately 67% of the total emissions during the construction phase, was associated with hauling operations and discharges from the ventilation system (via the Watut and Nambonga declines). During the operational phase of the Project, the power plant was assessed to be the major source of PM_{10}, contributing approximately 70% of the total estimated PM_{10} emissions.

Maximum ground level suspended particulate concentrations and dust deposition rates were predicted by the modelling to comply with the adopted screening criteria (refer to Section 7.1.1.1) at surrounding villages for both the construction and operational scenarios. Based on the conservative background inputs adopted in the modelling, no health-related impacts were anticipated as a result of particulate emissions from mining operations.

Mobile equipment combustion

Emissions of combustion products from mobile plant and machinery were qualitatively evaluated by SLR with emissions expected over a large area that will be well-diluted before they can travel beyond the mine area. The potential for elevated off-site concentrations as a result of these emissions is therefore considered to be negligible.

6.2.1.2 Infrastructure Corridor

Air emissions from the operation of the concentrate, tailings and fuel pipelines were considered to be minimal however construction of the pipelines has the potential to generate dust from earthworks and construction activities. The qualitative risk evaluation of human health impacts was generally determined to be ‘low’ or ‘negligible’ at all locations and could be reduced where appropriate mitigation measures are applied.

There is potential for vehicle exhaust emissions and wheel-generated dust to occur along the Project access roads during the operational phase. No significant adverse air quality impacts would occur as a result of the vehicle exhaust emissions given the remote location of the site and the low numbers of vehicles estimated to be using the roads (e.g. 20 to 40 vehicles per day for the Northern Access Road).

Proposed management measures to minimise any potential for nuisance dust impacts from wheel generated dust on the Project access roads include maintenance of roads and suppression of dust where high activity or dry conditions are present in the vicinity of sensitive receptors (SLR, 2018).

6.2.1.3 Coastal Area

Air emissions from the operation of the Port Facilities Area and Outfall Area were considered minimal. Dust generated during construction activities were evaluated qualitatively and the risk of potential health impacts were expected to be negligible.

6.2.2 Mine wastewater discharge modelling

Mine waste water, the majority of which will be from dewatering of groundwater and surface water inflows to the Watut and Nambonga Declines Portals and block caves, will be collected for testing and treatment (if necessary) at the water treatment plant north of the Watut Process Plant. This water will either be used to fulfil process plant water demands or discharged to the Lower Watut River. Management of these facilities will continue throughout construction and operations as required.

The Watut and Miapilli Waste Rock Dumps, constructed to store waste rock from development of the Watut Declines Portal and the Nambonga Decline Portal, will be designed and constructed to appropriately manage potentially acid-forming (PAF) material (by encapsulating in non-acid-forming (NAF) material) and the seepage and runoff will be captured and treated if necessary prior to discharge. Runoff and seepage from the Miapilli Waste Rock Dump will be treated if necessary to meet environment permit conditions (at a defined monitoring location to be agreed with CEPA) prior to being discharged to Nambonga Creek.

Based on the assumptions above, water modelling was undertaken by BMT WBM (2018) to predict surface water quality in receiving environments downstream of Project disturbances for the:

- Construction phase (nominally 5[2] years), wet season and dry season – treated mine wastewater is discharged directly to the Watut River via a wastewater discharge pipeline, and sediment loads from disturbed areas.

The modelling scenario focussed primarily on the potential impacts of mine wastewater discharge to the Watut River via the wastewater discharge pipeline during the construction phase, given the Project is predicted to have a water deficit for the majority of operations (i.e., greater process water requirement than mine water production). Modelling of sediment loads during the construction and operation phases was also undertaken as discussed in Section 6.2.3.

Villager residents in Study Area 1 access waterways for drinking water (generally as secondary sources), and for recreational/bathing purposes. This water source is consumed unfiltered for metals prior to ingestion, indicating the total metal concentrations would be most relevant for the HHRA assessment. However, treated mine dewatering water discharged to the Watut River will comprise minimal solids on the basis that the sludge generated as a by-product from water treatment during construction will be stored in geotubes (and later-during operations-directed to the process plant for metal recovery and disposal). For this reason, the modelled dissolved metals concentrations for wastewater discharged to the Watut River was considered indicative of the likely impacts to drinking water quality. The modelling selected the following metals based on the results of geochemical studies, background water quality in relation to potential human health impacts and consideration of the potential impacts to surface water values in the Project area: arsenic, copper, manganese, nickel, selenium and zinc.

The Study Area for the BMT WBM modelling included the Lower Watut River system (including the Lower Watut River between Pekumbe and Goraris and its floodplain) and the Wafi River system (including the Wafi River upstream of Pekumbe, and tributaries such as Buvu Creek, Nambonga Creek, and the Hekeng River). It was noted in the BMT WBM report that the modelling was undertaken on the limited dataset available in relation to rainfall, flow and hydrologic and constituents (total dissolved solids, salinity and dissolved metals) data. These limitations constrained the model calibration and validation inputs which potentially reduce confidence in the modelling outputs.

While the discharge of treated runoff and seepage to Nambonga Creek has not been included in the model, increases above existing metal and metalloid concentrations in the creek below the discharge point are not expected based on the predicted water treatment plant capacity.

6.2.2.1 Construction - wastewater treatment overview and modelling outcomes

During construction, mine wastewater will be treated and discharged to the Watut River via the wastewater discharge pipeline. The key sources of mine wastewater that will be treated prior to discharge include:

- Groundwater and surface water inflow to the Watut and Nambonga Declines Portals[3] and block caves (which will require dewatering).
- Runoff and seepage from the Watut Waste Rock Dump.
- Treated sewage wastewater.
- Runoff from sludge produced as a by-product from wastewater treatment that is stored in geotubes.

[2] In BMT WBM (2018), the construction period is referred to as being 7 years, which is related to a previous construction schedule. This discrepancy is immaterial to the predicted model outputs.

[3] While the construction of the Nambonga Decline Portal is proposed to be developed approximately eighteen months to two years earlier than the Watut Declines, in the model the development of the Nambonga Decline Portal has been assumed to occur approximately three months prior to the development of the Watut Declines and subsequent block cave development. This is likely to have little bearing on the water quality results and would represent a conservative worst-case scenario

Clean surface water runoff, such as that diverted from upstream Boganchong Creek to facilitate construction and operation of the Watut Portal Terrace and runoff from the process plant terrace, will be directed downstream of the raw water dam located in Boganchong Creek.

All modelled concentrations of dissolved metals and metalloids in the Watut River at assessment point LTW6 (see Table 6.2 and Figure 6.2) downstream of the wastewater discharge pipeline (both pre-development and during construction when discharge of treated mine wastewater is occurring) during the dry and wet seasons were below the adopted health screening criteria for drinking water. These criteria are also protective of recreational or washing activities (refer to Section 7.1.4), as presented in Table 6.1. This is a result of the low concentrations of metals and metalloids in the treated discharge, along with the large dilution factor provided by flows in the Watut River of approximately 1:45. This approximate dilution rate was calculated assuming a nominal point approximately 3km from the discharge point in the Watut River.

The maximum COPC levels pre-development and during construction are presented in Table 6.1.

Table 6.1: Predicted dissolved metals and metalloid concentrations (in the Lower Watut River approximately 3km downstream of the mine water discharge) downstream of Wongkins village

Scenario	Units	Chemical							
		Arsenic	Lead	Mercury	Zinc	Copper	Nickel	Selenium	Manganese
Modelled COPC concentrations – 50% percentile (dissolved metals)									
Maximum 50% percentile pre-development (1)	mg/L	0.0044	- (2)	- (2)	0.011	0.003	0.002	0.005	0.021
Maximum 50% percentile during construction	mg/L	0.0044	0.0003 (2)	0.0003 (2)	0.011	0.003	0.002	0.005	0.021
Adopted background concentration (4)	mg/L	- (3)	0.001	0.006	0.002	0.005	0.0035	0.026	0.013
HHRA Tier 2 (T2) baseline assessment (total metals)									
Concentrations adopted in Tier 2 (T2) baseline assessment	mg/L	0.0002	0.01	0.0001	0.018	NA	NA	NA	NA
Tier 1 (T1) Screening criteria									
Drinking water	mg/L	0.01	0.01	0.001	3	2	0.07	0.01	0.5

1. *Based on modelled concentration used in the BMT WBM study*
2. *COPC not modelled; however, a semi-quantitative assessment was estimated at the point of discharge.*
3. *Not provided in BMT BTM report.*
4. *Event mean concentration indicative of the upper end of natural variability. Calculated based on dissolved metal data collected during periods of high flow.*

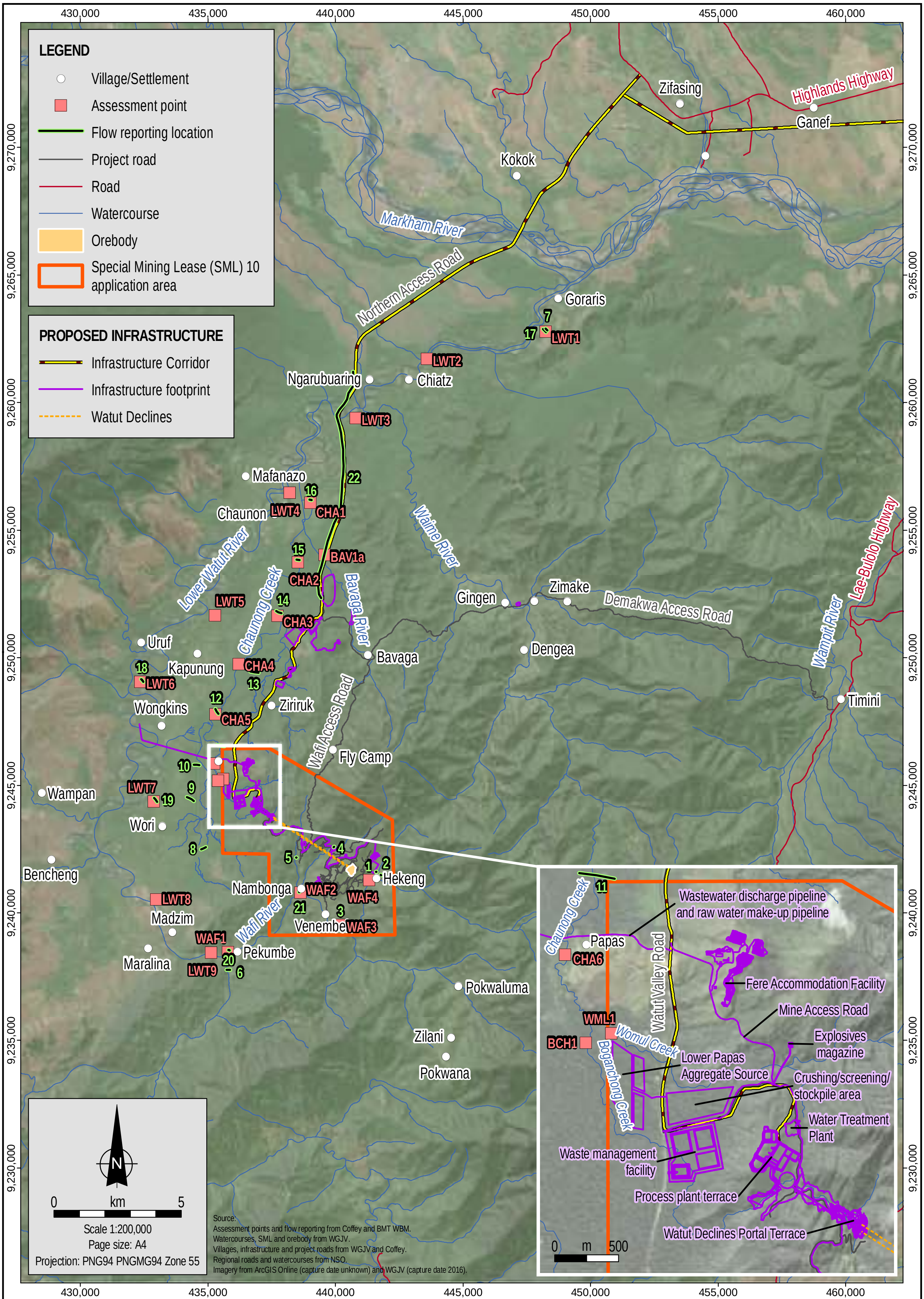
The assessment locations used in the modelling are listed in Table 6.2 and shown in Figure 6.2.

Table 6.2: Assessment points – modelled for dissolved metals

Watercourse	Site ID	Description
Chaunong Creek	CHA1	Downstream of Bavaga River confluence
Chaunong Creek	CHA2	Upstream of Bavaga River confluence
Chaunong Creek	CHA3	Downstream of Bobdul Creek confluence
Chaunong Creek	CHA4	Upstream of Bobdul Creek confluence
Chaunong Creek	CHA5	Downstream of Womul and Boganchong Creek confluence
Chaunong Creek	CHA6	Upstream of Papas village
Lower Watut River	LWT1	Downstream of Chiatz village downstream of Waime River confluence
Lower Watut River	LWT2	Downstream of Chiatz village
Lower Watut River	LWT3	Upstream of Ngarubuaring village
Lower Watut River	LWT4	Downstream of Chaunon village
Lower Watut River	LWT5	Downstream of Uruf and Kapunung village
Lower Watut River	LWT6	Downstream of Wongkins village
Lower Watut River	LWT7	Adjacent to Wori village
Lower Watut River	LWT8	Downstream of Madzim and Maralina villages
Lower Watut River	LWT9	Downstream of Wafi River confluence
Wafi River	WAF1	Upstream of Watut River confluence (downstream)
Wafi River	WAF2	Downstream of Nambonga village
Wafi River	WAF3	Upstream of Venembele village
Wafi River	WAF4	Downstream of Hekeng village
Womul Creek	WML1	Upstream of Chaunong Creek confluence
Boganchong Creek	BCH1	Upstream of Chaunong Creek confluence
Bavaga River	BAV1a	Downstream of proposed quarry

*Locations where maximum levels are predicted are in **bold***

Primarily associated with capture and treatment of mine wastewater prior to discharge, the maximum concentrations of predicted dissolved metal concentrations at assessment point LPW6, located downstream of Wongkins village, were below the adopted Tier 1 (T1) screening criteria for drinking water and therefore further quantitative Tier 2 (T2) modelling was not warranted. Based on the modelling outcomes of dissolved COPC concentrations estimated in receiving waterways, the health risks associated with the proposed wastewater discharge pipeline to the Lower Watut River were considered to be generally consistent with baseline conditions.



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Wafi-Golpu Project

Assessment point locations

Figure No: **6.2**

6.2.2.2 Mine operations – wastewater treatment overview

Mine wastewater discharge during operations was not modelled because for the majority of the time during this phase, processing water requirements indicate the Project will have a water deficit (i.e., greater process water requirement than mine water production) and therefore the discharge of wastewater to the Watut River during the operational phase is not expected, with the exception of two periods associated with reduced mill feeds caused from the transition between the block caves. These discharges are expected to be lower than those predicted during construction. Waters collected from clean water diversions and runoff will continue to be directed to the sedimentation pond. Contaminants in seepage from the Watut Waste Rock Dump and directed to the sedimentation pond and/or raw water dam downstream of the process plant terrace, will be reused as a part of the Project water supply or treated and released if required. Sludge produced from the treatment of wastewater is proposed to be directed through the process plant.

6.2.2.3 Mine closure

The assessment of the potential impacts to groundwater (WGJV, 2018) following mine closure were reviewed in relation to the block caves and the subsidence zone formed as a result of the ore extraction. The final block caves are predicted to result in a total subsidence zone volume of approximately $109Mm^3$**.** The dewatering required during mining operations will cease and recharge of the area is expected as a result of vertical infiltration of rainfall and lateral groundwater recharge. Infiltration of water from the subsidence zone to the underlying material, which hosts epithermal mineralisation with high acid-forming potential, is likely to result in poor water quality (low pH (approximately pH 4) and elevated metals concentrations) within the cave voids.

Generation of poor quality groundwater within the block caves represents a potential source of long-term impact to groundwater discharge features, particularly the groundwater springs on the eastern slopes of Mt Golpu, Nambonga Creek and Wafi River. People who currently use the springs as their preferred potable water supply are to be relocated prior to mine construction, and modelling predicts that this impact may persist for over 50 years following mine closure. The Conceptual Closure and Rehabilitation Plan (Attachment 2 of the EIS), proposes closure objectives for the management of water quality and human access to the subsidence zone after mine closure. The likely time frame for contaminated groundwater reaching Wafi River and Nambonga Creek has not been estimated but could reasonably be expected within 50 years post-closure.

The potential direct and indirect impacts to human health are likely to be significant in the event groundwater of this quality discharges to springs or waterways. The volume of contaminated water that people might be exposed to is dependent on whether re-activated springs and groundwater-fed surface water features return to pre-mining flows and whether resettled communities undertake activities in the area that could constitute an exposure pathway. This impact is likely to persist for over 50 years following mine closure. Ongoing studies will be undertaken to characterise groundwater flow from the block caves and the likely discharge points. At present it is not possible to determine which receptors may be exposed in the future and which exposure pathways may require management to address potential health risks. Therefore, appropriate management measures will be considered further, prior to mine closure, to ensure human health or food sources are not impacted.

6.2.3 Sediment transport modelling

Sediment transport modelling was also undertaken for the wet and dry season to evaluate Project derived sediment during the five-year construction and 27-year operations periods (BMT WBM, 2018). The modelling considered sediment loads rather than contaminants associated with the sediments. However, coarse-scale catchment modelling of construction disturbance areas by BMT WBM (Appendix I) assessed that, on a whole-of-catchment basis, sediment loads associated with construction and operational phases would contribute a very small proportion annually (approximately 0.21% and 0.07% respectively) to the high natural loads of the Lower Watut River main channel. Furthermore, sediment deposition decreases exponentially with distance from Boganchong Creek main channel or its distributary channels on the floodplain. Therefore, mine-derived coarse-grained sediments in Boganchong Creek are unlikely to reach Chaunong Creek or the receiving Bavaga and Lower Watut River main channels limiting the potential for contaminants in sediment to impact water sources of downstream villages. Impacts of sedimentation and increased total suspended solids are predicted to be highly localised and short-term, primarily occurring during the construction phase.

Furthermore, the modelling assumed no management measures were in place and therefore, implementation of measures in the Erosion and Sediment Control Plan will likely result in reduced sediment loads and concentrations downstream compared to the model outputs.

The modelling assumptions and results indicated:

- The majority of sediment deposition associated with construction and operation phases will be restricted to the eastern Watut River floodplain sub-catchment areas and floodplain creeks, and particularly the Boganchong and Womul creeks and the eastern escarpment and backplain of Chaunong Creek and the Bavaga River. Sediment deposition is expected to decrease exponentially with distance from Boganchong Creek main channel or its distributary channels on the floodplain (Pickup, 2015a and Pickup, 2015b).
- Sediment loads are predicted to be elevated for a short period during construction (approximately 18 months to two years on average) and are expected to recover during operations when the construction sites will stabilise and surface soil erosion will reduce due to both proactive rehabilitation and revegetation.
- Construction of sedimentation ponds downstream of the Project facilities including the Watut Declines Portal Terrace and process plant terrace, will limit sediment transport downstream.
- Most of the sediment that is not captured by the sedimentation ponds or raw water dam (downstream of the process plant terrace) is likely to be deposited on the Lower Watut River's eastern floodplain (i.e., its eastern backplain). The flow of sediment-laden high or flood flows across backplain vegetation results in a dropping out (sedimentation) of coarse-grained sediment particles by reduced water velocities and the trapping efficiency of vegetation.
- Modelled sediment impacts are likely to be relatively localised and implementation of measures in the Erosion and Sediment Control Plan are likely to result in a reduction to these sediment load predictions.

Exposures to contaminants in soils and sediments in waterways by humans may occur during gardening or other water related activities such as fishing. On the basis that the potential release of sediments during construction activities that will disturb soils or sediments will be managed/minimised via an Erosion and Sediment Control Plan, in addition to the processes outlined to settle and capture suspended solids during operations, exposures to downstream villages are likely to be acute (short term). Potential exposures relating to Project activities were therefore assumed to be minimal however baseline exposures were addressed via a Tier 1 (T1) screening assessment of the available soil and sediment data to determine whether exposures to contaminants warranted further quantitative assessment.

6.2.4 Port Area Facilities

Resulting filtrate generated as a by-product at the concentrate filtration plant is predicted to comply with the adopted marine water quality criteria prior to discharge in the vicinity of Berth 6. Port Area Facilities are designed to hold the equivalent of 24 hours of filtrate to cater for maintenance and unplanned outages on the wastewater treatment plant. Potential impacts to human receptors in the area are not considered to be significant where such occurrences are rare and remedied within 24 hours.

6.2.5 DSTP Outfall Area

The proposed Outfall Area will be located between Wagang and the mouth of the Busu River 6.3km east of the Port Facilities Area and includes the Outfall System comprising the mix/de-aeration tank, seawater intake pipelines and DSTP outfall pipelines. It will also include a laydown area, diesel storage, parking and associated access road. The primary waste from the outfall system is mine tailing transported via the tailings pipeline. Tailings will be discharged via the outfall pipes below the surface at approximately 200m depth. Upon entering the marine environment, the tailings will mix with and entrain seawater before final deposition on the ocean floor of the Markham Canyon in Huon Gulf.

Studies to model the movement of tailings once discharged were undertaken (Tetra Tech, 2018b; Coffey, 2017e), in addition to the study of bioaccumulation and biomagnification of metals in marine biota conducted by Tetra Tech (2018a) sought to understand the potential impacts to the marine environment and to receptors in Study Areas 3 and 4. The outcomes of the Tetra Tech study and the implications on human health is discussed in greater detail in Chapter 12.

6.3 Contaminant transport pathways

Based on the Project description the following key features and activities have been identified for further consideration in the HHRA, as presented in Table 6.3. The sources and contaminants considered to be managed as a result of the implementation of Project Environmental Management Plan (refer to Section 5.4) have been italicised. These sources and associated contaminants, and pathways have not been evaluated further where the proposed management measures are understood to minimise the potential release of contaminants at these source areas.

Table 6.3: Potential source identification

Feature/activity	Source media	Potential contaminants	Transport Pathway
Mine Area			
Clearing and topsoil removal from the mine development areas including: • Portal Terrace • Decline entrances • Watut Process Plant terrace • Access roads • Laydown areas • Ancillary infrastructure	Disturbed soil and exposed soil surfaces *Waste rock stockpile/dump*	Metals and metalloids *Particulate matter (PM_{10})*	• *Dust (1)* • *Leaching to runoff waters* • *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
	Air emissions from vehicles	*Particulate matter (PM_{10})* Gaseous nitrous oxide (NO_2) and sulphur dioxide (SO_2)	• *Dust (1)* • Air
Storage and distribution of fuel and oils • Bulk fuel storage area • Diesel generators and associated infrastructure • Workshops and wash-down bays	*Spills, leaks of fuels to soils*	*Petroleum hydrocarbon mixtures*	• *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
Mine area operations including: • Conveyor belt transport • Portal Terrace • Decline entrances • Watut Process Plant terrace • Access roads	*Exposed waste rock* *Exposed coarse ore*	*Metals and metalloids*	• *Dust (1)* • *Leaching to runoff waters* • *Leaching to groundwater* • *Runoff to surface waters*
	Air emissions from power generators	*Particulate matter (PM_{10})*	• *Dust (1)* • Air

Feature/activity	**Source media**	**Potential contaminants**	**Transport Pathway**
• Ancillary infrastructure • Power plant	Air emissions from vehicles	Gaseous nitrous oxide (NO_2) and sulphur dioxide (SO_2)	
Water and sediment ponds	*Wastewater seepage/discharge and sediment discharge.*	*Metals and metalloids*	• *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
Waste treatment facility and wastewater discharge pipeline	*Leaks, spills to surrounding soils* Wastewater	Metals and metalloids Landfill leachate	• *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters* • Discharge of wastewater (1)
Mine Closure Block caves and subsidence zone	AMD generation	Low pH Metals and metalloids	• Groundwater discharge to waterways (1) • Groundwater extraction (1)
Infrastructure Corridor			
Construction of Infrastructure corridor and access roads	Disturbed soil and exposed soil surfaces	*Metals and metalloids* *Particulate matter (PM_{10})*	• *Dust* • *Leaching to runoff waters* • *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
	Air emissions from vehicles	*Particulate matter (PM_{10})* *Gaseous nitrous oxide (NO_2) and sulphur dioxide (SO_2)*	• *Dust* • *Air*
Vehicle use of access roads	*Air emissions*	*Particulate matter (PM_{10})* *Gaseous nitrous oxide (NO_2) and sulphur dioxide (SO_2)*	• *Dust* • *Air*
Concentrate pipeline	*Potential leaks to surrounding soils or directly to water bodies*	*Metals and metalloids*	• *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
Fuel pipeline	*Potential leaks to surrounding soils or directly to water bodies*	*Petroleum hydrocarbon mixture*	• *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
Terrestrial tailings pipeline	*Potential leaks to surrounding soils or*	*Metals and metalloids*	• *Leaching to groundwater and*

Feature/activity	Source media	Potential contaminants	Transport Pathway
	directly to water bodies		*discharge to surface water bodies* • *Runoff to surface waters*
Coastal Area			
Construction of Port Facilities Area including concentrate filtration plant and materials handling, storage and ship loading facilities at the Port of Lae Construction of Outfall System and access road	*Disturbed soil and exposed soil surfaces*	*Metals and metalloids* *Particulate matter (PM10)*	• *Dust* • *Leaching to runoff waters* • *Leaching to groundwater and discharge to surface water bodies* • *Runoff to surface waters*
	Air emissions from vehicles	*Particulate matter (PM10)* *Gaseous nitrous oxide (NO2) and sulphur dioxide (SO2)*	• *Dust* • *Air*
Processing, stockpiling, re-handling and loading of concentrate onto bulk carrier ships and the off-loading of bulk fuel and diesel from ships	*Spills, leaks to marine waters*	*Metals and metalloids* *Particulates* *Petroleum hydrocarbons.*	• *Marine water*
Outfall System including mix/de-aeration tank, laydown area, diesel storage	*Spills, leaks to shoreline marine waters*	*Metals and metalloids* *Particulates* *Petroleum hydrocarbons*	• *Marine water*
DSTP	Discharge of tailings to Huon Gulf at a depth of 200m	Metals and metalloids Particulates	• Marine water

Italicised text indicates these sources, contaminants and transport pathways are expected to be managed as part of the implementation of the Project Environmental Management Plan and therefore have not been evaluated further.

1. *Evaluated in Section 6.2 however also assessed in the baseline assessment*

Other low-volume contaminant sources associated with ancillary infrastructure such as workshops, offices, construction camp, laboratories, flocculants and reagent storage, sewage treatment plants, security building, general waste disposal storage and the explosives magazine have not been considered in the HHRA as it is assumed the risks will be mitigated by routine site management and mitigation measures common to the mining industry. Examples of this include bunding storage areas, using oil-water separators to reduce hydrocarbon concentrations in hydrocarbon-impacted runoff water, routine waste management housekeeping and having safety buffers around hazardous areas such as the explosives magazine. The exception to this is the assessment of treated sewage effluent co-disposed with mine wastewater during construction via the wastewater discharge pipeline.

The focus of the HHRA is on planned contaminant releases associated with waste discharges and emissions; therefore, unplanned events such as a rupture of the concentrate pipeline, terrestrial tailings pipeline or fuel pipeline are not addressed in this report.

6.3.1 Selection of chemicals of potential concern for the Tier 1 (T1) screening assessment

Based on the Project activities identified in Section 6.2 and the testing of surface soils (Klohn Crippen Berger, 2013), ore and tailings leachate (Clean TeQ, 2017), waste rock (SRK, 2018) and surface waters (BMT WBM, 2017), the following were identified as likely contaminants of potential concern (COPC) for the Tier 1 (T1) screening assessment:

- Metals: antimony, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel selenium and zinc – selected based on abundance and toxicity to humans[4] and aquatic biota.
- Particulates (PM_{10}), NO_2 and SO_2. – ambient air based contaminants present as a result of dust generation and combustion of fossil fuels.

The COPCs selected for quantitative evaluation in the Tier 2 (T2) assessment were further refined based on the outcomes of the Tier 1 (T1) assessment.

6.3.2 Preliminary conceptual site model

A preliminary conceptual site model was developed based on the locations, behaviours of COPCs in various source media and their potential transport. The preliminary conceptual site model forms the basis for identifying potential receptors and the selection of potentially complete exposure pathways.

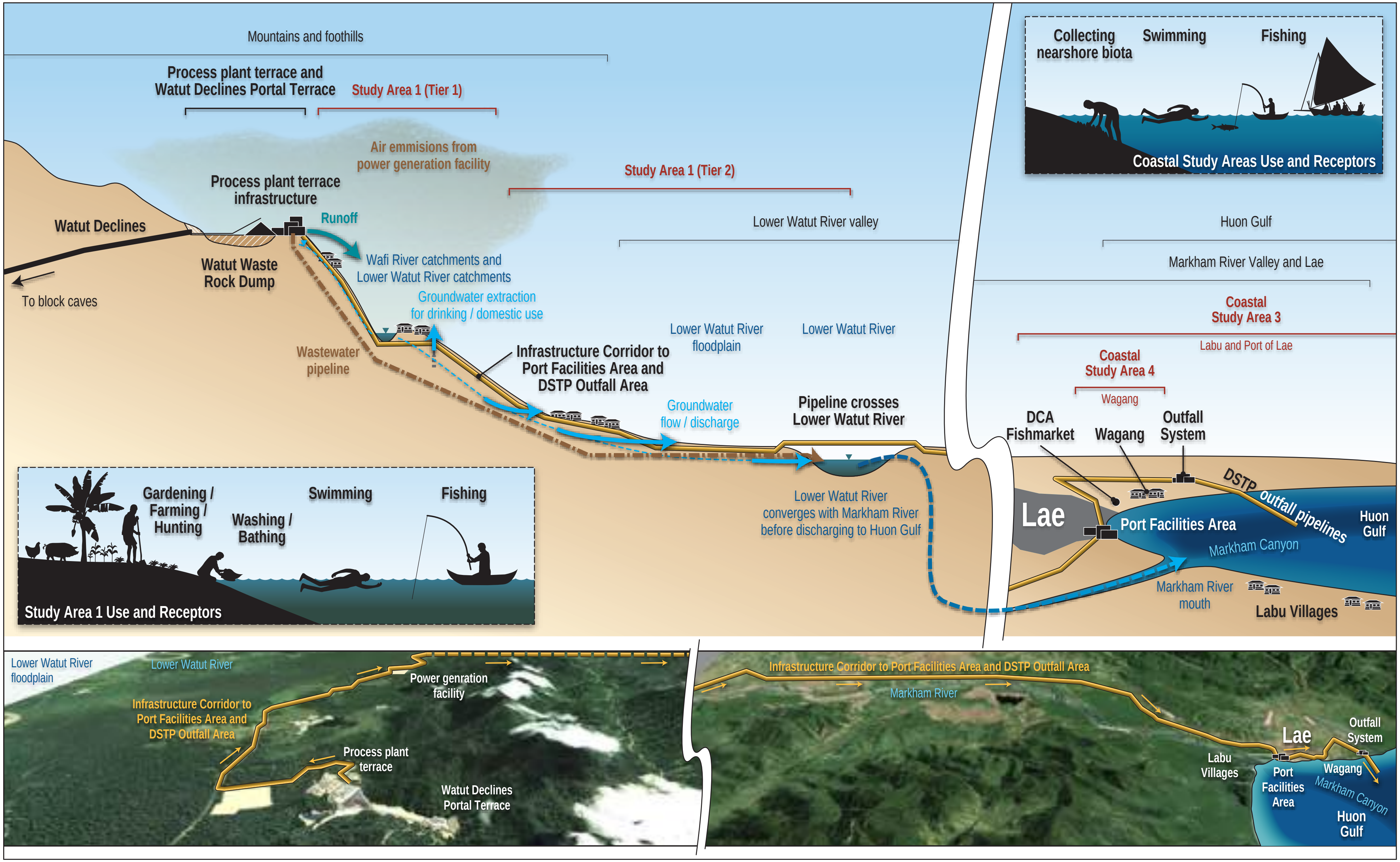
6.3.2.1 Project source and transport summary

The sources of contaminants associated with mine construction, operation, transport activities and DSTP identified in Table 6.3 are generally expected to be managed via the implementation of the Project Environmental Management Plan. The selected source and transport pathways selected for further consideration include:

- Air emissions from power generators and vehicles:
  - Where transportation of contaminants could be in the form of particulate matter or gas emissions resulting from dust generation as a result of clearing and construction, facility development, transport, and rock stockpiles, and gas emissions due to operation of the power station, machinery and vehicles.
- Wastewater discharge and sediment discharge:
  - Where dissolved contaminants or suspended solids from wastewaters, are discharged to downgradient surface waters such as Watut River.
- Discharge of mine tailings to the Huon Gulf at a depth of 200m:
  - Where dissolved contaminants or suspended solids from mine tailings disposal, are discharged to marine waters in the Huon Gulf.
- Infiltration of acid and metalliferous drainage (AMD) to groundwater:
  - Where groundwater pH is low and dissolved contaminants are discharged to springs or waterways post mine closure.

Based on the identified contaminant sources and transport pathways, the conceptual site model and potential exposure pathways to receptors are presented in Figure 6.3. The conceptual site model and exposure pathway analysis is further refined based on the behaviours and resources of receptors in study areas that may potentially be affected. Additional refinement is undertaken in the T1 (Tier 1) screening assessment, as well as the quantitative Tier 2 (T2) evaluation.

[4] Copper, zinc and selenium are essential micronutrients; however they may be toxic when in excess of human requirements. Arsenic, cadmium, lead and mercury do not have a known beneficial role in humans.



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WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

Conceptual site model

Figure No: 6.3

6.4 Receptor identification

This section describes each study area in detail and is informed by the Socioeconomic Baseline (Coffey, 2018c, Appendix T of WGJV (2018)). Receptors can be identified based on their location in relation to the potential transport of contaminants released the Project. Receptor's exposures are also dependant on their behaviours which are often determined by environmental factors and the resources available at each location. The following descriptions provide the information required to refine the selection of receptors and the potential routes of exposure.

6.4.1 Study Area 1 – mine environs and access corridors.

This study area comprises 28 villages, located near the proposed mine and nearby infrastructure. The study area also includes villages located along or near the Demakwa Access, Wafi Access and Northern Access roads, and along the Lower Watut River. These villages were grouped together due to their proximity to the proposed mine facilities, infrastructure and access corridors. Villages within this study area are further divided into two study tiers, Tier 1 and Tier 2, according to impacts potentially experienced if the Project were to proceed.

Study Area 1 (Tier 1) villages are those situated near Mount Golpu and proposed mine infrastructure. Tier 1 villages are inhabited by people of the Hengambu, Yanta and Babuaf cultural groups, who reside in the following 16 villages:

- **Hengambu:** Hekeng, Fly Camp, Bavaga and Gingen.
- **Yanta:** Venembele, Nambonga, Pekumbe, Pokwaluma, Pokwana and Zilani.
- **Babuaf:** Madzim, Wori, Wongkins, Kapunung, Papas and Ziriruk.

It is proposed that the Hekeng, Venembele and Nambonga villages are to be resettled in the Study Area 1 (Tier 2) area prior to mine construction (Coffey (2018c), Chapter 5 of Appendix T of WGJV (2018)).

Study Area 1 (Tier 2) villages are those situated along or near the Demakwa Access, Wafi Access and Northern Access roads and those villages along the Lower Watut River. The Study Area 1 (Tier 2) villages include:

- Villages along/near the Northern Access Road: Kokok, Chiatz, Ngarubuaring, Mafanazo.
- Villages along/near the Demakwa Access Road: Timini, Dengea, Zimake.
- Other villages along the Lower Watut River: Uruf, Wampan, Bencheng, Maralina, Goraris.

Within this study area, Tier 2 villages are those which may be directly impacted or affected by Project activities, due to being located proximal to Project infrastructure, access corridors or a waterway potentially impacted by the Project.

Baseline setting

The topography within this study area is steep and mountainous, transitioning to the generally flat Watut River floodplain to the west. Heavy rainfall and steep, unstable slopes result in high sediment loads in local rivers and creeks after rainfall. The water and sediment quality of watercourses in the study area is generally consistent with that found in other regions of PNG, with the exception of significantly elevated levels of mercury which have been noted within the study area (the cause of which is unknown).

Air quality and noise levels in the study area generally reflect the remote, forested location. Noise sources are predominantly natural: wind, insects, animals and the activities of daily village life. The main influences of air quality are fires either used for cooking, forest clearance (for subsistence gardens and growing cocoa) and dust lift-off from traffic on dirt roads.

Subsistence agriculture is the most important livelihood activity across the study area with villagers generally dependent on the natural environment for food, housing materials, firewood and medicine, which were either grown in gardens or gathered from the surrounding forests. Hunting and fishing are commonly practiced subsistence activities. Local residents hunt animals such as wild pigs, cassowaries, marsupials including bandicoot and other small mammals, wild fowl, flying foxes, grubs and lizards.

The rivers and streams provide a major source of cash income (through alluvial mining), and are also used for fishing, washing and, along the Watut, as a transport route. Alluvial mining is more frequently undertaken in the villages along the Wafi River than those along the Watut River. Water from the Watut River is generally not used for drinking (except as a secondary source) because the river water often contains sediment or detritus which affects taste and perceived water quality. The information relating to water resources are predominantly based on Tier 1 villages where the majority of surveys have been undertaken.

The main source of water is not available all year round for some villages (which is likely due to the smaller streams utilised for piped water supply drying up in periods of low rainfall. In villages that have a basic reticulated water supply, most were installed up to 30 years ago and often require repairs. The most common issues with the reticulated water systems were noted to be the contamination of water with dirt, sediments and dust in periods of high rainfall.

Many of the water sources of the streams provide recreational areas for children for swimming and as places for women to meet. Water resources also provide a source from which aquatic materials such as plants can be harvested for food (e.g. water cress and *Ipomea aquatica*), medicinal and cultural purposes. Stones used to retain heat for cooking were also collected from watercourses.

The most commonly grown produce in Study Area 1 are bananas, greens/kumu, kaukau (sweet potato), taro and sugar cane. The traditional diets in all villages in Study Area 1 relied on garden produce, supplemented by hunting, collecting and fishing. While collectively these sources make up greater than 97% of their diet, the consumption of store foods is higher than expected, particularly considering many of the villages are relatively isolated, and appears to have risen substantially in the last decade.

A variety of freshwater aquatic fauna were reported consumed as food by households. The most common species caught in the study area were eels, catfish and carp. Prawns were also identified as an important source of food in some villages, along with turtles and crocodiles. Aquatic plants, such as kangkong and watercress, are also harvested and consumed as kumu (leafy green vegetables). While Pekumbe, Madzim, Chiatz, Goraris, Bencheng and Uruf have fish ponds, most villages relied on nearby rivers, streams and lakes for fishing and the collection of other aquatic biota.

Fishing is a commonly practiced activity in all villages surveyed and was carried out by 79% of households on a weekly basis, inclusive of 3% of households who reported as fishing on a daily basis. The remaining households (21%) reportedly fished on a monthly basis. No seasonal changes to fish species caught were reported.

Several people indicated that there are fewer fish and prawns than previously. While some of these people attributed the decline in fish and prawn availability to mine exploration and the associated increase in sedimentation, it may also reflect increased disturbance and sedimentation resulting from alluvial mining, increased fishing pressure as a result of rapid population growth and possibly by the presence of invasive exotic fish species.

The data show that mercury is not apparently used, or commonly used in Hekeng, Venembele or Nambonga for alluvial mining, as nuggets or flakes of gold are found, and generally contain no or few impurities. Mercury is commonly used at Pekumbe and in villages along the Watut River, both during panning and heating, as methods to extract impurities. At the time of the survey, no people from outside the Mine Area had migrated in and set up alluvial mining activities along Wafi River. Several people indicated that this would not be allowed on their customary owned land. However, people from Pekumbe did indicate that their relatives from other Yanta villages (e.g., Zilani) did visit to earn income from gold.

6.4.1.1 Study Area 1 (Tier 1)

The 16 Study Area 1 (Tier 1) villages had an estimated population of 3,869 persons in 2017. Study Area 1 (Tier 1) villages are located amid the steeper terrain (Hengambu and Yanta villages) and on the flat Watut floodplain (Babuaf villages). Vegetation clearing around villages is the result of gardening for food production.

The floodplain east of the Watut River into the foothills is actively used for livelihood activities including food gardens, growing cocoa trees, hunting small animals, accessing household water supplies, fishing in streams, harvesting forests for timber and other products. Most of the Tier 1 villages are located near major rivers or streams. Villages which are located furthest away from a major river or stream were Pokwaluma, Zilani and Pokwana, along with the hamlet of Fly Camp. These villages relied on springs as a key source of water for drinking and domestic uses.

The majority of villages relied on piped water as their primary source of drinking water with the exception of Wori and Ziriruk, which relied on groundwater or a nearby creek. Generally, piped water supply is sourced from springs or streams (untreated) at an elevation higher than the village, which is piped into a central locality within the village. Water outlets were shared communally by all households. One third of the villages (Bavaga, Madzim, Papas and Ziriruk) have no secondary source of drinking water, with the remaining villages relying on creeks, springs and water holes, which surround the villages, or groundwater and rainwater. For bathing, villagers predominately used water from nearby rivers and creeks followed by piped water. Groundwater was not used for washing. Only four villages (Hekeng, Kapunung, Papas and Pekumbe) had a tank to collect rainwater; which was generally attached to a school or aid post.

6.4.1.2 Study Area 1 (Tier 2)

The 12 Study Area 1 (Tier 2) villages had an estimated population of 6,000 persons in 2017. Study Area 1 (Tier 2) villages are located amid steep terrain along the Northern Access Road, on the Lower Watut floodplain and along the Demakwa Access Road. Several Study Area 1 (Tier 2) villages are located in close proximity to the Watut River.

Water sources identified for Uruf, Mafanazo, Chiatz and Goraris were piped water supplies sourced from springs or streams (untreated) at an elevation higher than the village. The water was generally tapped and piped into a central locality within the village and the water outlets were shared communally by all households. Ngarubuaring village primary water source is Ngarubuaring River. The water sources for other villages in the Study Area 1 (Tier 2) were not identified.

The creeks and rivers all flood periodically with the flooding of the Watut River valley floodplain forest occurring annually. Gardens in the vicinity of Madzim, Wori, Wongkins and Kapunung are all susceptible to flooding as are some gardens in the other villages which have been built near streams or rivers.

6.4.1.3 Study Area 1 – Potential impacts from proposed Project

Study Area 1 (Tier 1) villages are located along waterways downstream of the Mine Area, and Study Area 1 (Tier 2) villages are located closer to the Watut River where the greater contaminant load is likely to be concentrated as a result of Project construction activities. However, on the basis the release of sediments to waterways, either directly or via runoff will be managed during all construction works, these exposure pathways are not considered further.

Study Area 1 (Tier 2) villages located on the Lower Watut River, at Wongkins and further downstream of the wastewater pipeline outlet, are also potentially exposed to higher levels of contaminants in the event mine water discharge is not managed appropriately. Dissolved phase contaminant modelling indicates discharges from the wastewater pipeline to the Lower Watut River during the construction phase will not exceed adopted drinking water or recreation screening criteria (refer to Chapter 7) and are not expected to increase risks significantly above baseline conditions. On the basis contaminant concentrations in the Lower Watut River are not predicted to present a potential health risk above baseline conditions for these communities, it is reasonable to assume they will not present a potential health risk for villages further downstream.

Study Area 1 (Tier 1) villages are likely to experience greater impact to their waterways during the construction period. Sediments released to local waterways potentially act as an additional contributor of dissolved and total metals that may be ingested directly or indirectly via aquatic foods and plant food sources which are grown or collected within flood zones. Based on the management measures proposed to minimise sediment release during construction activities, exposures via these pathways will be controlled.

The proposed management of waste rock leachate and other potential sources of sediment and dissolved contaminants in water during the operation phase are understood to include the collection and treatment of leachate and runoff therefore the release of contaminants is expected to be minimal. The power generation plant located within Study Area 1 has the potential to pose health impacts to villages as indicated in the air modelling predictions. The dust modelling predictions suggest dust levels during construction and operations are unlikely to impact Study Area 1 where proposed management measures are implemented.

6.4.2 Study Area 2 – Infrastructure Corridor from Zifasing to Lae

The Infrastructure Corridor will connect the Mine Area to the Coastal Area. Study Area 2 relates only to the portion of the Infrastructure Corridor from Zifasing village to the western border of Lae Urban Local Level Government. This study area includes Zifasing village, and traverses parts of Yalu village, Wampar villages, including Ganef, Gabsonkeg, Nasuaupum and Munum.

Water sources were not identified for Zifasing, Ganef and Markham Farm areas; however drinking water was reportedly sourced from springs and wells, with nearby creeks an auxiliary source of water at Durung Farm, Gabsongkeg village and Munum. Yalu village sources water via via a pipeline from the Yalu River to the village.

Communities within this study area are anticipated to experience impacts arising from the construction of the concentrate, fuel and the terrestrial tailings pipelines. Most potential impacts associated with the pipeline construction are likely be short-lived and restricted to a narrow area. All pipelines within the infrastructure corridor will contain leak detection and flow control mechanisms to ensure any releases are noted early and any impacts are minimised.

On this basis, these villages will only be impacted during the construction phase and measures are proposed to manage the release of contaminants via soil or runoff. Villages are therefore unlikely to be affected by longer term Protect activities; consequently, this study area is not considered further in the HHRA.

6.4.3 Study Area 3 – Lae and Labu villages

This study area comprises the city of Lae and Labu villages. The surrounding area includes the Labu villages to the south (Labu Butu, Labumiti and Labu Tale). People within this study area may experience impacts arising from Project activities that would take place at or near the Port of Lae, from the construction of the concentrate, fuel and terrestrial tailings pipelines or indirectly via the DSTP.

The extent to which food is grown in Lae has not been investigated through primary data collection. Due to their access to commercial food sources and employment, and the lack of animals and plants within the city, the majority of residents of Lae are not expected to rely on gardens as a major food source. Similarly, low levels of hunting are expected to occur in the Labu villages as they are considered more likely to be reliant on fishing and to a lesser extent, food purchased at stores.

Many residents of the city of Lae have access to piped water as well as relying on water tanks and wells. Piped water is sourced from groundwater, with Water PNG Limited providing 30 million litres of treated water daily to residents of the city of Lae and surrounding villages. South of Lae, people of

Labu villages do not have access to piped water. Potential water sources include springs, creeks, rainwater tanks and wells.

The Huon Gulf is located immediately offshore from Lae, as well as from the Labu villages south of Lae. Artisanal fishing groups in the Huon Gulf are small-scale, low-technology, low-capital fishing groups. The fishing groups generally use handline methods targeting both demersal and pelagic fishes in water depths usually between 50m and 100m, while some used trolling to target fish in shallower areas to depths of 10m. The Labu people, located south of the mouth of the Markham River, are known to rely heavily on coastal fisheries including the Labu Lakes, Markham River and nearshore marine waters. Fishing is important to the Labu people for both subsistence and commercial purposes. Fish, prawns, crabs and shellfish are commonly harvested through use of handlines, gill and seine nets (the latter having smaller mesh), small hand-held nets and collection of shellfish by hand. Villagers are known to generally fish six days per week via boats or canoes. The boats head south with the morning winds and return on the afternoon southerly winds. The catch is sold at the DCA Point fish market and to a lesser extent the main street market in Lae, with the remainder taken for personal or village consumption.

Along the southwestern Huon Coast nesting area near Labu Butu, Labu Tale, Busama, Salamaua and further south, leatherback sea turtle eggs and green sea turtle meat are collected and consumed.

Study Area 3 - Potential Impacts from the proposed Project

Villages located south of the Port of Lae may currently be exposed to dissolved contaminants and sediments discharged to Huon Gulf associated with Markham River waters. The potential impacts to these villagers may be increased as a result of future contaminants, associated with Project activities, in river water discharge and/or the DSTP, and subsequent indirect impacts to foods they consume that are caught or collected in local habitats and the Huon Gulf. The contribution of contaminants in Markham River water discharging to Huon Gulf is expected to be minimal on the basis the release of sediments will be managed and the dissolved metals in wastewater discharge to the upstream Lower Watut River during construction is predicted to be minimal.

The management procedures proposed for the Port of Lae Facility suggest the release of contaminants will be contained and managed appropriately thereby minimising exposures to receptors in the study area.

6.4.4 Study Area 4 – Wagang and Yanga villages

This study area comprises the villages of Wagang and Yanga, two peri-urban villages which are located approximately 2km east of Lae. Residents of both Wagang and Yanga villages engage in subsistence activities, such as gardening, fishing, gathering and hunting. Surplus produce (e.g., garden crops or fish) were reportedly sold for income.

People within this study area may experience impacts arising from the construction and operation of the Project facilities within the proposed Outfall Area. The Project facilities include the terrestrial tailings pipeline, which runs through or adjacent to areas used by Wagang and Yanga residents, and the proposed DSTP. The Outfall Area is approximately 1km northeast from the coastal village of Wagang.

Wagang

Wagang village is a coastal village located approximately 3km east of Lae. Gardening has reportedly diminished in importance over the last few years with people in Wagang increasingly dependent on store-bought and market foods. It was estimated that approximately 40% of food consumed in Wagang village was harvested from gardens. The most commonly grown produce was kumu, coconut, sweet potato (*kaukau*), tapioca, sugar cane, pit pit (a type of cane), cucumber and beans. Hunting may be undertaken two or three times per year however hunting had declined in recent years due to a decrease in game.

Water is sourced from groundwater and provided via communal taps and is a key source of drinking water for Wagang village, as well water contained in rainwater tanks. Households further away from the communal taps tend to rely on rainwater tanks, springs, and wells. Areas in the network of creeks around Wagang village were designated as bathing areas, and as areas for washing laundry and dishes. These creeks are located to the east of Sipaia Road, and on either side of the coastal portion of the village.

Fishing is a common activity in Wagang as approximately one third of households reported fishing for fin fish daily or several times a week, while another third reported fishing on either a weekly or monthly basis. The remaining third indicating they did not fish. Most fishing occurs at the beach; however rivers, creeks, mangroves and the open sea are also utilised. While some households own boats and canoes used for fishing, most fishing did not occur further than 500m from the shore where water depths exceed 100m and are greater than 250m within about 1,000m from shore. Based on the village's fishing equipment and low numbers of deep slope fish in the area, the catching and consumption of deep slope fish is likely to be considered negligible.

It cannot be ruled out that some people at Wagang may attempt to catch deep slope fish, some of the time, although the findings of the deep slope and pelagic fish study completed for the EIS by Coffey and Marscco (Coffey, 2018b) reported anomalously low catches of deep slope fish species in the waters offshore from Wagang (and elsewhere in the Huon Gulf) compared to the results from other similar studies in PNG.

It was reported that locals fish for target species such as red emperor, trevally and shark at a narrow nearshore rocky reef located between Wagang and the Busu River; however more fish were caught at the mouth of the Busu River than at the rocky reef structure. Compared to fin fish, invertebrate aquatic resources (such as prawns, crabs and shellfish) are less commonly collected.

Most of the fish caught by villagers from Wagang are taken for personal or village consumption, and are generally caught using handlines from the beach. Other foods are obtained from the estuarine environs associated with the Busu River. In Wagang the types of other aquatic foods include crabs, prawns and shellfish (although these are likely to be from creeks). West Pacific leatherback sea turtles are opportunistically caught and eaten and their nests harvested for eggs. In household surveys, respondents recorded consuming fresh fish and other seafood twice a week however households appeared to be more dependent on canned fish, which was reportedly consumed on average six days per week. Approximately 35% of respondents purchased fresh fish from shops and markets.

The network of creeks to the east of Sipaia Road were reported to be a source of food such as finfish, eels, freshwater turtles, crabs, crayfish and aquatic plants (watercress and sago). The beach in Wagang was reportedly a recreational destination for people residing in Lae, who go to Wagang beach to swim, have picnics and socialise.

Yanga

In Yanga food is primarily sourced at the village trade store, secondarily from household gardens and thirdly at Lae markets. The key crops are banana, taro, yam, greens *(kumu)* and sweet potato however other crops such as marita, cassava, cocoa, sugar cane, peanuts, betel nut, tobacco (*brus*), coconut and sago were also reported.

Hunting was undertaken once a month and meat sourced was not essential for regular village diets but important for special feasts. Typical species hunted included bandicoots, flying foxes, wild fowls, wild pigs, birds and lizards.

Residents of Yanga village reported sourcing drinking water from streams, springs, rain tanks and wells. Bukaho stream, located approximately 1km east of the village, is perennial and the main water source for the village. Drinking water was sourced from this location daily for those in the village without an alternative water source, which required a half-hour return walk from the village. The quality of water from the Bukaho stream was considered poor due to sediment from the Busu River entering Bukaho stream and some households used rainwater tanks during the wet season whilst other houses relied on wells (approximately 6m deep) for drinking water. A reticulated water supply system was installed in the village with a main connection pipe located at the school headmaster's house. However, the system is currently not working and there is no connection to houses from the main connection pipe. The source of the water supply is not known.

Domestic water used for cooking, bathing and laundry was supplied from the same sources as drinking water, with water tanks and reticulated water systems only functional during the wet season. Men and women predominantly bathed in a creek a 10 minute walk from the village, and also bathed in water drawn from wells.

In Yanga, fishing is predominantly in estuaries and within mangrove areas; however, some walk approximately 30 minutes to the coastline to fish in the ocean from the beach, mostly at the mouth of the Busu River. Yanga villagers reported fishing several times a week for approximately half a day however fishing is not relied upon as a household food source. People in Yanga village did not report owning or fishing from boats.

In Yanga village, types of fish caught included marine trevally, red emperor and freshwater tilapia, carp, eels and invertebrates including prawns, king shells and salt-water and mud crabs. Respondents also reported occasionally catching crocodiles for consumption. Marine turtles and their eggs were not harvested by people of Yanga village. Fish and shellfish caught by villagers are relied upon as a food source, as well as freshwater plants (watercress) and prawns.

Study Area 4 – Potential Impacts from the proposed Project

Villagers located east of the Port of Lae may be impacted by the discharge of dissolved contaminants and sediments into the Huon Gulf associated with Project activities including the Outfall Facility, the proposed DSTP and discharge to Markham River. An increase in the nature or level of contaminant has the potentially to indirectly impact the foods that are caught or collected in the Huon Gulf and subsequently consumed by villagers.

Based on water modelling and the implementation of the proposed management measures for the Outfall Facility, the contaminants in discharging river waters to marine waters are not expected to increase as a result of Project activities. The potential exposure pathways associated with the DSTP are discussed in greater detail in Chapter 12.

6.4.5 Source and transport pathways

6.4.5.1 Baseline

Based on the identification of receptors, their behaviours and food and water sources, these receptors may currently be exposed to the selected contaminants associated with the Project via:

- Air emissions.
- Transportation of contaminants in the form of particulate matter or gas emissions resulting from dust generation as a result of clearing and burning activities or local traffic and industry in more urban areas.
- Freshwater sources (including groundwater) and associated sediments.
- Contaminants dissolved in water or in sediments as a result of natural transport and deposition of sediments particularly during the wet season, via landslides or anthropogenic sources such as artisanal mining.
- Marine waters and sediments.
- Contaminants dissolved in water or in sediments as a result transport via Markham River and other rivers discharging to the Huon Gulf.

6.5 Exposure routes

6.5.1.1 Receptors of concern

Villages located in Study Area 1 are considered to be the closest receptors to COPCs in transported media (i.e., surface waterways, groundwater and wastewater discharges) and therefore the most sensitive receptor in relation to health risks as a result of construction and operation activities. Villages located along the Coastal Area in Study Area 3 and Study Area 4 are closest to the Outfall Area and DSTP. Villagers are known to regularly source and consume locally caught seafood and biota.

Residents of Lae, also included in Study Area 3, generally obtain their drinking water via a reticulated water supply and the majority of their foods from local stores. The baseline assessment of Study Area 3 is therefore considered to represent Labu villagers, those whose main food sources are reliant on local sources and fishing. Lae residents have therefore not been specifically addressed further on the basis Labu villagers are more likely to be exposed to Project related contaminants if present, and are therefore the focus of the baseline assessment.

6.5.1.2 Exposure routes

Routes of exposure whereby a contaminant may enter the body are via inhalation, ingestion and dermal contact. Examples of exposure routes that may be relevant to this assessment include:

- Inhalation of contaminants that volatilise readily such as found in fuels or air emissions.
- Inhalation of contaminants in airborne particulate matter.
- Ingestion of contaminants in food and water (and incidental ingestion of contaminants in other forms such as dust, soil and aerosols).
- Dermal contact with contaminants in media such as soil, sediment and water.

The physico-chemical characteristics and extent of the COPC and the behaviour of the receptors of interest will determine the method of exposure and subsequent systemic absorption.

The exposure pathways for human receptors in the selected study areas to potential contaminants associated with baseline and mining activities are presented in Table 6.4.

Table 6.4: Plausible exposure pathway evaluation – human receptors

Potential COPC Source	Transport	Exposure point	Exposure route	Potential receptors in Study Areas	Selected for Baseline / Project impact evaluation
Air Emissions	Volatiles in air	Outdoor air	Inhalation of volatiles	Area 1	Y
				Area 3	N
				Area 4	N
	Particulates transported in air	Plant via foliage or soil deposition and uptake	Ingestion of contaminated food	Area 1	Y
				Area 3	N
				Area 4	N
		Terrestrial animal uptake		Area 1	Y
				Area 3	N
				Area 4	N
		Direct Contact Pathways	Incidental ingestion	Area 1	Y
				Area 3	N

Potential COPC Source	Transport	Exposure point	Exposure route	Potential receptors in Study Areas	Selected for Baseline / Project impact evaluation
			Particulate inhalation Dermal contact	Area 4	N
Water	Surface water: Freshwater and marine water(1)	Domestic Purposes	Direct ingestion Dermal contact	Area 1	Y
				Area 3	N
				Area 4	N
		Recreation	Incidental ingestion Dermal contact	Area 1	Y
				Area 3	Y
				Area 4	Y
		Soils or sediments in areas associated with sediment deposits from flooding events	Ingestion of garden/crop plants grown in floodplain. Incidental ingestion Dermal contact	Area 1	Y
				Area 3	N
				Area 4	N
		Fishing, hunting	Ingestion of animals (including animal products) inhabiting/ utilising surface waters	Area 1	Y
				Area 3	Y
				Area 4	Y
	Groundwater	Domestic Purposes	Direct ingestion Dermal contact	Area 1	Y
				Area 3	N
				Area 4	N

1 Assumed to be freshwater in Study Area 1, and marine water in Study Area 3 and Study Area 4.

In order to determine the baseline exposures to human receptors within the selected study areas to the identified contaminants and exposure pathways in each study area, baseline data from was obtained from the following media:

- Ambient air.
- Water (drinking water, freshwater bodies, marine water and groundwater).
- Food (market basket surveys, and aquatic biota from marine or freshwater habitats).
- Sediment/soil in floodplain.

7 Human health risk assessment – Baseline

This section presents the screening criteria selected for the Tier 1 assessment and the baseline technical reports with data collected from each of the receiving environments. The data is summarised in this section and the sampling locations are presented on figures in Appendix A and the data sets are provided in Appendix B.

7.1 Tier 1 (T1) screening assessment

A Tier 1 (T1) screening assessment compares measured chemical concentrations in each identified media with guideline criteria or standards developed by various health or environmental agencies. The criteria are generally derived using scientific studies and other safety factors to estimate chemical specific doses that are considered to have no adverse effects.

The selection of screening criteria has been sourced from the following agencies:

- PNG government agencies (Ministry of Health, 2014).
- Joint FAO/WHO Expert Committee on Food Additives (JECFA).
- World Health Organization (WHO).
- International Programme on Chemical Safety (IPCS).
- United States Environment Protection Agency (USEPA).
- Canadian Council of Ministers for the Environment (CCME).
- United States Health and Medicine Division (HMD).

The selection of appropriate criteria is discussed further in each environmental media section below.

7.1.1 Air

7.1.1.1 Screening criteria – Air

PNG does not currently have specific statutory air quality requirements. International guidelines were therefore reviewed to select appropriate screening criteria for total suspended particles, PM_{10} (particulate matter less than 10 microns in aerodynamic diameter), $PM_{2.5}$, NO_2 (nitrogen dioxide) and SO_2 (sulphur dioxide). In addition to these standard air contaminants, the deposition of dust is also considered to be a nuisance and dust deposition monitoring stations have been in place at a number of villages since 2011 therefore screening criteria was also included. Screening criteria have been selected from the following sources:

- WHO Air Quality Guidelines: WHO Air Quality Guideline – Global Update – Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide (WHO, 2005)
- USEPA Office of Air Quality Planning and Standards (OAQPS): National Ambient Air Quality Standards (USEPA, 2010).
- USEPA Integrated Science Assessment (2017)
- European Union: European Commission Air Quality Directives.
- Australian Regulatory Guidelines: Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW OEH, 2005).

Sulphur dioxide

The SLR (2018) air emission modelling indicated SO_2 is currently predicted to be present at elevated concentrations during operations as a result of intermediate fuel oil combustion at the power generation facilities. An in-depth appraisal of international air quality standards was therefore undertaken for SO_2. The review noted many countries directly adopted or derived their air quality standards from either the WHO or USEPA.

The most recent published national assessment of SO_2 is the USEPA Integrated Science Assessment (2017). The USEPA standard is a 1-hour level of 195 µg/m^3 based on a 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour concentrations. The USEPA found the 1-hour standard provides protection against SO_2-related health effects associated with short-term exposures ranging from 5 minutes to 24 hours. The 1-hour standard is expected to be protective of health effects following acute exposures (5−10 minutes associated with the adverse respiratory effects in asthmatics), in addition to chronic exposures as reported in epidemiological studies associated with more serious health effects that generally daily metrics (1-hour daily maximum and 24-hour average).

The 1-hour standard has been adopted by other national jurisdictions including the European Union, United Kingdom, Sweden and New Zealand who have all adopted a 1-hour guideline of 350 µg/m^3. The WHO have not set a 1-hour level for SO_2. On the basis a 1-hour standard is considered the most appropriate (based on the 2017 assessment of this standard by the USEPA), and the fact national jurisdictions such as the European Union, United Kingdom, Sweden and New Zealand, all specify a 1-hour SO2 standard of 350 µg/m3, the Project adopted the guideline of 350 µg/m3 as derived by the European Union (1999). The review of SO_2 health effects and derivation of international guidelines is presented in greater detail in Appendix D.

Adopted health screening criteria

The adopted screening criteria are consistent with those used in the air quality baseline assessment (SLR, 2018). The WHO sourced guidelines were selected where available on the basis that these air quality guidelines are generally more conservative than other international screening criteria. The WHO have not set total suspended particulates guideline and only Australia has derived dust deposition guideline. The selected screening criteria are summarised in Table 7.1.

Table 7.1: Ambient Air Quality Screening Criteria [µg/m^3]

Pollutant	Averaging period	Ambient Air Quality Standard	Reference
Nitrogen dioxide (NO_2)	1 hour	200	WHO 2005
	Annual	40	WHO 2005
Sulphur dioxide (SO_2)	1 hour	350 (1)	EU 1999
Total suspended particulates	24 hours	150	USEPA, 2010
	Annual	75	USEPA, 2010
Particulate matter ($PM_{2.5}$)	24 hours	25	WHO 2005
	Annual	10	WHO 2005
Particulate matter (PM_{10})	24 hours	50	WHO 2005
	Annual	20	WHO 2005
Dust deposition	Annual (incremental)	2 g/m^2/month	NSW OEH, 2005
	Annual (cumulative)	4 g/m^2/month	NSW OEH, 2005

1. *Reported as a 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour concentrations.*

7.1.1.2 Baseline data – Air

Baseline data was not collected in the Mine Area as it was assumed the background concentrations of gaseous pollutants and particulate matter would be negligible. This assumption is reasonable given the remote location of the proposed mine, the dense vegetation, high rainfall and low wind speeds of the area. In addition, villages currently located in the proposed Mine Area would be resettled prior to construction.

Baseline air quality monitoring has been conducted outside of the Mine Area in Study Area 1. A monitoring program to characterise existing air quality in Study Area 1 (Tier 1) was conducted between 11 May 2011 and 14 May 2011 (Coffey Environments, 2011). Four villages in proximity to the Mine Area were selected for the characterisation survey of dust deposition rates and PM_{10} concentrations. These villages were:

- Wongkins, located approximately 5.5km northwest of the Portal Terrace.
- Wori, located approximately 4km west of the Portal Terrace.
- Bavaga, located next to the junction of the existing Wafi Access Road and Link Road.
- Madzim, located approximately 6km southwest of the Portal Terrace.

A dust deposition monitoring program at the same locations has been ongoing since June 2011 and Hekeng has also been monitored since 2015.

Total suspended particulates and $PM_{2.5}$ were not measured in the baseline air quality programs.

No baseline air quality monitoring data is available for Study Area 3 or Study Area 4. Vehicle and industrial emissions from sources located in Lae, in addition to emissions from ships entering and berthed at the Port of Lae, have the potential to result in elevated baseline concentrations of NO_2, SO_2 and particulates in Study Area 3.

Baseline air quality data is not available for Study Area 4 however given the coastal location, the existing air quality was expected to be similar to that in Study Area 1 (SLR, 2018).

The Tier 1 (T1) screening assessment of available baseline data are summarised in Table 7.2.

Table 7.2: Ambient Air Quality Screening Assessment for Study Area 1 [µg/m^3]

Pollutant	Averaging period	Screening criteria	Baseline Data
Particulate matter (PM_{10})	24 hours	50	4 – 33
	Annual	20	NA
Dust deposition	Annual (incremental)	2 g/m^2/month	1.6 – 2.4 (1)
	Annual (cumulative)	4 g/m^2/month	

NA – not available

1. Based on averages from each village from June 2011 to May 2015.

No exceedances of the selected screening criteria were identified in the limited baseline sampling undertaken to date within Study Area 1.

The results indicate that:

- The highest ambient PM_{10} concentrations were measured at Wongkins and Bavaga whilst the lowest concentrations were reported at Wori and Madzim.
- Slightly elevated dust deposition rates, above the adopted screening criteria, have been measured at Wori and Bavaga on occasion, however these may have been due to activities occurring in and around the villages such as the burning of vegetation and land clearance for gardens or construction of new dwellings

7.1.2 Soil and deposited floodplain sediment

The soil assessments undertaken in the study areas generally related to geochemical assessments of the mine area. Disturbed soils and rocks in the mine area or other areas associated with mine construction or operations, permit small particles to be exposed at the surface. These soil particles are transported in water runoff during rain events, travelling along drainage lines to nearby water courses. During flooding events, which occur during wet season, sediments from waterways are deposited to soils in river floodplains that are used for growing crops. The Lower Watut River features large flood plains that are present along both sides of the river as it meanders from Madzim to the Markham River. Villages located in the vicinity of the Lower Watut River are known to use the floodplains for growing crops and home grown produce.

The assessment of soils in village gardens is considered relevant where sediments related to the proposed Project activities are likely to be deposited in soils where the villagers may come into direct contact and where edible plants or other foods are grown or collected and subsequently ingested by villagers. Whilst an investigation of floodplains soils, particularly in areas known to be used for food product, has not been undertaken, sediment data obtained within the Lower Watut River have been used to assess baseline conditions in the absence of more specific floodplain soil data. It has been assumed sediment data would overestimate contaminant concentrations in this instance.

7.1.2.1 Screening criteria – Soil and sediment

To assess risks to human health from COPCs in soil or sediments, guideline values were adopted from the CCME (2007) Soil Quality Guidelines for the Protection of Environmental and Human Health for agricultural land as presented in Table 7.3.

Table 7.3: Human Health Soil Screening Criteria [mg/kg]

Compound	CCME – Agriculture Standard
Antimony	20
Arsenic	12
Cadmium	1.4
Chromium	64
Copper	63
Lead	70
Mercury	6.6
Molybdenum	5
Nickel	45
Selenium	1
Zinc	200

7.1.2.2 Baseline data – Soil and sediment

Streambed sediments have a more significant impact on ecological receptors than human health. However, in the absence of a baseline data set for floodplains soils in Study Area 1 (Tier 2), sediment concentrations have been adopted on the assumption the available sediment data is likely to be indicative of soils in the floodplain areas where crops are grown for local consumption. The screening criteria adopted for soils are considered appropriate to screen sediments in this instance as the incidental ingestion and dermal contact pathways were also considered.

The assessment of baseline sediment quality considered data captured by BMT WBM in 2015 (BMT WBM, 2018a) from various sites along the Lower Watut River. Whilst the sampling methodology is not available, it is likely the sediment samples were obtained within the water course rather than in floodplain areas used for agriculture. The BMT WBM sampling sites included in the data assessment of the floodplains relating to the Lower Watut River were Goraris, Uruf, Chiatz, Bali Oxbown, Womul DS and Uruf Oxbow.

Soil sampling conducted by Klohn Crippon Berger (2013) in the Mine Area, Watut Camp, Nambonga Creek and the Old Portal Road found elevated levels of arsenic, lead, antimony, selenium and zinc based on the calculated Geochemical Abundance Index. These metals or metalloids were found to exceed the average crustal abundance in natural soils primarily from the Mine Area and Nambonga Creek. The analytical data for the concentrations of these metals in soil were not provided in the study report.

7.1.2.3 Baseline assessment – Soil and sediment

Sediment data obtained as part of the BMT WBM sediment transport assessment (BMT WBM, 2018a) were adopted for the screening assessment. The sediment data may present higher concentrations of metals than floodplain soils given the potential contributions from upstream sources (existing mining operations or landslides) and artisanal mining in the river and its associated catchments.

The mean values for COPCs in surface soils and sediments are compared to the adopted screening criteria presented in Table 7.4.

Table 7.4: Human Health Soil and Sediment Screening Assessment [mg/kg]

Compound	CCME – Agriculture Standard	Mean Sediment Concentration Lower Watut River
Antimony	20	0.5
Arsenic	12	12
Cadmium	1.4	0.1
Chromium	64	44
Copper	63	41
Lead	70	NA
Mercury	6.6	0.1
Molybdenum	5	NA
Nickel	45	34
Selenium	1	***1.6*** (1)
Zinc	200	72

*Notes: **Italicised bolded text** indicates exceedance of adopted criteria*

NA Not analysed

1. *Below the human health screening criteria in an agricultural scenario. Refer to discussion in the text.*

The calculated mean concentrations of selenium detected in sediment were based on samples collected at Goraris, Uruf, Chiatx, Bali oxbow and Womul. The reported concentrations ranged between 1.2 mg/kg and 2.2 mg/kg, the results exceeded the adopted soil criteria for agricultural use, indicating the background concentrations in sediment is above the acceptable level in an agricultural setting (includes ecological and human receptors). The CCME standard criteria for selenium in an agricultural setting was based on the protection of more sensitive ecological receptors via direct contact rather than human exposures, given ecological receptors are considered the more sensitive in this scenario.

The screening criteria for selenium based on a human health endpoint is 80mg/kg in an agricultural setting, therefore the exceedance is not considered to indicate a potential health risk (CCME, 2007).

7.1.3 Drinking water

7.1.3.1 Screening criteria – drinking water

To assess risks to human health from COPCs in drinking water, guideline values were adopted from:

- PNG Public Health (Drinking Water) Regulation 1984.
- WHO (2017) Guidelines for Drinking-Water Quality, 4th edition.

The adopted criteria are presented in Table 7.5.

Table 7.5: Drinking water screening criteria [mg/L]

Compound	Screening Criteria (1)	
	PNG	WHO
Antimony	-	0.02
Arsenic	0.05	0.01
Cadmium	0.01	0.003
Chromium	-	0.05
Copper	-	2
Lead	0.1	0.01
Mercury	0.001	0.006
Molybdenum		0.07
Nickel	-	0.07
Selenium	0.01	0.01
Zinc	-	3.0 (1)

1. *Based on aesthetic quality. A health based guideline has not yet been derived.*

The lowest guideline values presented in Table 7.5 have been adopted as the screening criteria for the Tier 1 (T1) screening evaluation.

7.1.3.2 Baseline data – drinking water sources

Primary drinking water sources Study Area 1

Primary drinking water sources vary across villages in Study Area 1, similarly with secondary and bathing sources. All known water sources are presented in Table 7.6, based on information obtained in the Socioeconomic Baseline (Coffey, 2018c) and the drinking water investigation (WGJV, 2017).

Table 7.6: Study Area 1 water sources – drinking and bathing

Village	Sampled	Primary source of drinking water	Secondary source of drinking water	Water for bathing
Bavaga (Tier 1)	9th Sept 2017	Piped water from Zumandia Creek	No secondary source	Bavaga River
Hekeng (Tier 1)	9th Sept 2017	Piped water from Zumandia Creek	Spring fed water hole at Wigo Creek	Piped water from Zumandia Creek. Also Hekeng Creek and Wigo Creek
Venembele (Tier 1)	8th Sept 2017	Piped water from Mioka Creek and Flowing Creek	Wafi Creek	Piped water from Mioka Creek and Flowing Creek
Kapunung (Tier 1)	7th Sept 2017	Piped water from Fetaf Creek	Watut River. Water hole along the Watut River bank which has been dug to catch water	Piped water from Fetaf Creek
Madzim (Tier 1)	7th Sept 2017	Piped water from Zezang Creek	No second source	Watut River or piped water from Zezang Creek
Nambonga (Tier 1)	8th Sept 2017	Piped water from Gwagonom Creek	Buvu Creek, Nambongo Creek and Wafi Creek	Piped water from Gwagonom Creek. Also use Buvu Creek, Nambongo Creek and Wafi Creek
Papas (Tier 1)	7th Sept 2017	Piped water from Fetaf Creek	No second source	Piped water supplied by WGJV from Wongkins Aid Post
Pekumbe (Tier 1)	7th Sept 2017	Piped water from Gwavenau Creek	Springs and small creeks along Wafi Creek	Piped water from Gwavenau Creek. Also use Wafi Creek
Wongkins (Tier 1)	7th Sept 2017	Piped water from Fetaf Creek	Groundwater	Piped water from small streams
Wori (Tier 1)	7th Sept 2017	Groundwater from shallow wells throughout the village	Spring and creeks: Chaunong Creek	Watut River
Ziriruk (Tier 1)	9th Sept 2017	Ziriruk Creek approximately 2 minutes' walk from the village.	No second source	Ziriruk Creek approximately 2 minutes' walk from the village.
Uruf (Tier 2)	NA (1)	Piped water sourced from 'Unum' area – water dam source	Uruf River	Uruf River and piped dam water from 'Unum' area.
Mafanazo (Tier 2)	NA (1)	Piped water from unknown source	Unknown Creek and spring	Unknown River
Ngarubuaring (Tier 2)	NA (1)	Ngarubuaring River	Watut River	Ngarubuaring River
Chiatz (Tier 2)	NA (1)	Piped water from unknown source	Unknown Creek (approximately 30 mins walk away)	Watut River

Village	Sampled	Primary source of drinking water	Secondary source of drinking water	Water for bathing
Goraris (Tier 2)	NA (1)	Piped water from unknown source	Watut River	Watut River and piped water from unknown source
Chaunon (Tier 2)	9th Sept 2017	Groundwater	Not known	Not known
Kokok (Tier 2)	NA (1)	Not known	Not known	Not known

1 Not applicable as Study Area – Tier 2 villages were not specifically sampled in the September 2017 investigation (Chaunon was the exception). Data obtained from catchment locations were adopted (refer to Table 7.9 in surface water section).

Primary drinking water sources Study Area 1 (Tier 1)

The drinking water investigation was undertaken in September 2017 by the on-site WGJV environmental team (WGJV, 2017). The investigation obtained drinking water samples from village piped water outlets and extracted groundwater wells, which provided the mean concentrations for drinking water sourced from local creeks or streams, and from groundwater in Study Area 1 (Tier 1). The water quality of samples collected included pH (6.71 – 8.44 groundwater, 8.32 -8.56 surface water), total suspended solids (< 445 mg/L) and total hardness as $CaCO_3$ (<1 – 201 mg/L groundwater, 77-148 mg/L surface water).

The drinking water investigation results are presented in Table 7.7.

Table 7.7: Drinking water 2017 investigation in Study Area 1, (Tier 1) – total metal concentrations [mg/L]

Compound	Screening Criteria	Concentration Drinking Water [(1)]											
		Kapunung	Wongkins	Wori	Madzim	Pekumbe [(2)]	Papas	Ziriruk	Chaunon	Bavaga	Hekeng	Venembeli [(2)]	Nambongo
Antimony	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.01	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Cadmium	0.003	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.05	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	0.002	<0.001
Copper	2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	0.01	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	0.07	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.07	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.016	<0.001	0.002	<0.001
Selenium	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
Zinc	3.0	0.009	<0.005	<0.005	0.013	<0.005	<0.005	<0.005	0.356	0.014	<0.005	<0.005	<0.005

1. *Drinking water analysis undertaken in Study Areas 1, all Tier 1 villages with the exception of Chaunon in Tier 2.*
2. *Maximum concentrations presented where more than one source sampled.*

Surface water sources – Study Area 1 (Tier 2)

The assessment of baseline surface water quality data includes data collected by WGJV, including water quality data collected between January 2006 and December 2016 (at 47 monitoring sites) and further water quality data from monitoring programs undertaken by BMT WBM in 2015 through 2016[5]. The majority of the WGJV water quality samples were collected during scheduled monthly sampling campaigns, which, for logistical reasons, typically occur when stream flows are low. Conditions in higher-flow periods are likely to be substantially different particularly with higher sediment loads.

The data selected for the Tier 1 (T1) screening evaluation of drinking water also considered other surface waterways on the basis the villages in the Tier 2 area of Study Area 1 may obtain their primary or secondary water from these sources (refer to Table 7.6). The highland waterways were generally considered to relate to Wafi River, Bavaga River and Waime River. The Lower Watut River and floodplains, including Womul Catchment, were considered relevant to Study Area 1 villages located in the lowlands and floodplain.

Data uncertainties

Although it is understood the WGJV data set was generally obtained under drier conditions, a number of uncertainties were identified. On the basis the WGJV data set was not provided with all identifiers that may assist in interpreting or adjusting the anomalies, the data set as a whole was considered separately to the BMT WBT data. A conservative approach was adopted in order to consider both sets of data and reduce the overall uncertainties.

The 50th percentile concentrations were calculated rather than mean concentrations for the WGJV data set. The maximum of the 50th percentile total metal concentration obtained from the WGJV data, and the mean concentration of total metals obtained from the BMT WBT data, were selected for the Tier 1 (T1) screening evaluation.

To address the uncertainties between the two data sets, including variations in wet and dry seasons at the point of exposures (i.e., drinking water taps/fountains, including secondary sources and bathing/swimming areas) further site specific sampling of primary and secondary water sources is proposed.

Groundwater sources – Study Area 1

The assessment of baseline groundwater quality data relies on the 2017 drinking water investigation which included sampling of groundwater at two villages in Study Area 1, Wori and Chaunon.

Surface water sources – Study Area 3 and Study Area 4.

Baseline studies of drinking water in Study Area 3 and Study Area 4 were not conducted on the basis the water supply for villages in these areas is unlikely to be impacted as a result of Project activities. A piped water supply is present for Lae and surrounding area. In Wagang, residents reported sourcing drinking water from springs, creeks, rainwater tanks and wells. Residents of Yanga village reported sourcing drinking water from Bukaho Creek (located approximately 1km east of the village), rainwater tanks and wells.

7.1.3.3 Baseline assessment – surface water sources for drinking purposes in Study Area 1.

The drinking water investigation undertaken in September 2017 (WGJV, 2017) provided the mean concentrations for drinking water sourced from local creeks or streams, and from groundwater in Study Area 1 (Tier 1).

Drinking water source information for most villages in Study Area 1 (Tier 2) were not identified therefore the mean surface water concentrations in Study Area 1 obtained from the wider sampling

[5] Data from 2017 was not included as it was not provided in a suitable format.

conducted over a number of decades were adopted as described in the previous section. The proximity of the sampled locations to drinking water sources in these villages is not known, therefore use of the mean concentrations was considered reasonable given Study Area 1 (Tier 1) may also use secondary sources included in the data set. The data sets for each source are presented in Appendix B and the calculated drinking water concentrations are compared to the screening criteria in Table 7.8.

Table 7.8: Drinking water screening assessment (1) [mg/L]

Compound	Screening Criteria	Mean Concentration Drinking Water Study Area 1 (Tier 1) (2)	Mean Concentration Extracted Groundwater Study Area 1(3)	Adopted Concentration (4) Sub catchments(5): Wafi River, Bavaga River, Waime River	Adopted Concentration (4) Lower Watut River and floodplains (6)
Antimony	0.02	0.001	0.001	0.0002	0.0002
Arsenic	0.01	0.001	0.001	0.002	0.01
Cadmium	0.003	0.0001	0.0001	0.0002	0.0001
Chromium	0.05	0.003	0.001	0.001	0.01
Copper	2	0.001	0.001	0.002	0.01
Lead	0.01	0.001	0.002	0.001	0.01
Mercury	0.001	0.0001	0.0001	0.0001	0.0001
Molybdenum	0.07	0.001	0.003	0.0002	0.0002
Nickel	0.07	0.003	0.001	0.003	0.01
Selenium	0.01	0.01	0.01	0.01	0.01
Zinc	3.0	0.01	0.18	0.01	0.02

1. *Note total metal concentrations have been calculated using the laboratory limit of reporting (LOR) where non-detects were reported.*
2. *Mean concentrations in drinking water piped from local streams/creeks in Study Area 1, Tier 1 villages only. Calculated median concentrations at Kapunung, Ziriruk, Papas, Kapunung, Nambonga, Venembele, Hekeng, Pekumbe, Madzim, and Bavaga in the 2017 investigation.*
3. *Average total metal concentrations in drinking water sourced from locally extracted groundwater at Wori and Chaunon.*
4. *Selected based on the maximum of the 50th percentile concentration using WGJV data and the mean concentration from BMT WBM data.*
5. *Selected total metal concentrations in surface water associated with the Study Area 1 villages generally located in the highlands. Calculated median concentrations at the following catchments Wafi River, Bavaga River and Waime River. Refer to the discussion in the text below regarding uncertainties in the data set.*
6. *Selected total metal concentrations in surface water associated with the Study Area 1 villages generally located in the lowlands and floodplains. Calculated median concentrations at the following catchments Lower Watut River, Lower Watut River floodplains and Womul River. Refer to the discussion in the text below regarding uncertainties in the data set.*

No exceedances of the drinking water screening criteria were identified for the chemical analytes in the 2017 baseline drinking water investigation which sampled drinking water sourced from local waterways and extracted from local groundwater wells. The results show the water sources in Study Area 1 (Tier 1) and groundwater in Study Area 1 are suitable for drinking as most results were below the laboratory limit of reporting (LOR) and the average concentrations were below the adopted screening criteria.

No exceedances of the drinking water screening criteria were identified for the chemical analytes in the adopted baseline surface water concentrations associated with the Lower Watut River and its catchments. Comparison of the drinking water screening criteria with the maximum adopted concentration from the mean concentration of total metals in the lowland or highland data from BMT

WBM data or the 50th percentile concentrations estimated from the WGJV, found no exceedances indicating the primary and secondary water sources in Study Area 1 (Tier 2) are suitable for drinking.

7.1.4 Surface waters associated with recreation, washing or bathing

In order to assess impacts to human health from COPCs in surface waters associated with recreation, washing or bathing, the adopted drinking water guideline values in the previous section were adjusted to take into account reduced ingestion rates associated with these exposures. Whilst direct contact exposures with skin and mucus membranes are likely to be the main exposures when washing clothes or undertaking secondary recreational activities such as fishing, ingestion is considered to be the greater contributor through bathing or swimming. This is particularly true for children who are more actively playing in the water and involuntarily ingest a greater amount water as a result.

PNG has yet to establish recreational water quality guidelines therefore a conservative adjustment of the drinking water screening criteria was adopted based on 100ml ingested per day. This corresponds to 20 fold increase of the drinking water criteria which is based on 2L ingestion per day. This is considered a reasonable adjustment given the recent review of ingestion studies conducted by enHealth, as presented in the Australian Exposure Factor Guide (enHealth, 2012a), which assumed children less than 15 years of age ingest 50mL/hr whilst swimming. The adjusted guideline is considered protective of a five year old child with a body weight of 15kg who spends two hours a day swimming.

7.1.4.1 Baseline data – fresh and marine waters

The assessment of baseline surface water includes WGJV and BMT WBM collected data as described in Section 7.1.3.2. The baseline data from both the highland catchments (Wafi River, Bavaga River and Waime River) and the Lower Watut River and associated floodplains, including the Womul River catchment, were selected to evaluate villagers in Study Area 1.

Water quality samples were collected adjacent to the Coastal Area and at reference locations near Labu Tale, Salamaua and east of the Busu River as part of the nearshore baseline assessment (Coffey, 2017). A total of 19 sites were sampled across two surveys; comprising 14 sites in November 2016 and 11 sites in February 2017. In February 2017, six of the sampling sites from the 2016 investigation were revisited, and a further five sites located around the Port of Lae were also investigated. Of the 24 nearshore locations sampled, 6 were considered to be representative of Study Area 3 and 11 were within Study Area 4. Only dissolved metal data was available as total metal analysis was not reported.

7.1.4.2 Baseline assessment – fresh and marine waters

The mean concentration of the selected metal COPCs in surface water (refer to Table 7.8) are compared to drinking water criteria (refer to Table 7.5) that have been adjusted for recreational exposures as presented in Table 7.9.

Table 7.9: Surface water screening assessment for recreational use [mg/L]

Compound	Screening Criteria (1)	Adopted Concentration Freshwater (2,3)		Mean Concentration Nearshore Marine Water (2,6)
		Sub catchments(4): Wafi River, Bavaga River, Waime River	Lower Watut River and floodplains (5)	
Antimony	0.4	0.0002	0.0002	NA
Arsenic	0.2	0.002	0.01	0.002

Compound	Screening Criteria (1)	Adopted Concentration Freshwater (2,3)		Mean Concentration Nearshore Marine Water (2,6)
		Sub catchments(4): Wafi River, Bavaga River, Waime River	Lower Watut River and floodplains (5)	
Cadmium	0.06	0.0002	0.0001	<0.001
Chromium	1	0.001	0.01	<0.001
Copper	40	0.002	0.01	0.001
Lead	0.2	0.001	0.01	<0.001
Mercury	0.02	0.0001	0.0001	<0.001
Molybdenum	1.4	0.0002	0.0002	NA
Nickel	1.4	0.003	0.01	0.011
Selenium	0.2	0.01	0.01	0.003
Zinc	60	0.01	0.02	0.002

NA Not analysed

1. *20 fold increase of the adopted drinking water criteria based on recreational use adjustment.*
2. *The LOR concentration was adopted for samples that reported a non-detect result.*
3. *Selected based on the maximum of the 50th percentile concentration using WGJV data and the mean concentration from BMT WBM data.*
4. *Selected total metal concentrations in surface water associated with the Study Area 1 villages generally located in the highlands. Calculated median concentrations at the following catchments Wafi River, Bavaga River and Waime River. Refer to the discussion in the text below regarding uncertainties in the data set.*
5. *Selected total metal concentrations in surface water associated with the Study Area 1 villages generally located in the lowlands and floodplains. Calculated median concentrations at the following catchments Lower Watut River, Lower Watut River floodplains and Womul River. Refer to the discussion in the text below regarding uncertainties in the data set.*
6. *Marine waters in the vicinity of the Study Area 3 and Study Area 4 based on concentrations measured at 1.5m depth at L4, M1, V1, V2, B1, LA1, LA2, LA3, LA4 and LA5 (WGJV, 2018) (Chapter 10). Concentrations for dissolved metals only.*

The adopted concentrations of total metals in freshwaters were below the recreational screening criteria. As discussed in the previous section, uncertainties associated with data quality suggests interpretation is limited. Comparison of the recreational water screening criteria with BMT WBM data obtained during 2015 and 2016 found no exceedances in the mean concentration of total metals in the lowland or highland data.

No exceedances of the adjusted drinking water screening criteria for recreational water use were identified for dissolved metal analytes in nearshore marine waters. The results show surface water in Study Area 1 and coastal Study Areas 3 and 4 are suitable for recreational uses.

7.1.5 Overview of screening criteria for food

Selected food items that were either grown, caught or collected by villages for consumption were compared against international food standards. However, standards have only been established by international agencies for selected metals, with a particular focus on those that are considered to be relatively more toxic, and more commonly known to be food contaminants.

A number of metals such as arsenic, cadmium, lead and mercury are naturally occurring chemical compounds in food. Metals can also occur as residues in food because of their presence in the environment (soil, water or the atmosphere), as a result of human activities such as artisanal mining, farming, industry or car exhausts, or from contamination during food processing and storage. Food standards have been determined by WHO in the Codex Alimentarius Commission (WHO, 2011) for a number of contaminants in foods. Similarly, the European Commission (EC, 2010) and Food Standards Australia and New Zealand (FSANZ, 2016b) also provide food standards.

For all of these regulatory authorities, the food standards are generally focussed on additives to foods (e.g., pesticides) and on those foods that can contribute significantly to the total dietary intake of a particular compound (such as mercury in shellfish). Therefore guidelines have only been established for cadmium, lead in plant foods, and arsenic, cadmium, lead and mercury in aquatic biota. It is expected that most foods will also contain essential nutrients that may cause health effects where the recommended guidelines are significantly exceeded. On this basis, copper, selenium and zinc have also been included in the screening assessment as they were detected at concentrations above the LOR in most samples.

Samples that report a non-detected result (below the laboratory limit of reporting) were assumed to have a value below the reported laboratory detection limit. Therefore, 50% of the laboratory detection limit was adopted, consistent with the Food Standards Australia and New Zealand methodology (FSANZ, 2016b).

7.1.6 Aquatic biota

Concentrations of selected metals in marine and freshwater biota were checked against recommended standards developed by Food Standards Australia New Zealand (FSANZ). The standards comprise the Australia New Zealand Food Standards Code – Standard 1.4.1 – Contaminants and Natural Toxicants (FSANZ, 2016a), and the Food Standards Australia New Zealand – Generally Expected Levels (GELs) for Metal Contaminants (FSANZ, 2001). The Standard 1.4.1 (Contaminants and Natural Toxicants) specifies the maximum levels of contaminants and natural toxicants that are permitted in the foods listed in the standard. The FSANZ GELs provide recommended levels that, if exceeded in foods, should be further investigated.

The guidelines generally apply to the flesh of aquatic biota (i.e., excludes shells, bone, cartilage and digestive tracts).

Table 7.10: Screening criteria for aquatic foods [mg/kg]

Compound	Screening Criteria Aquatic Biota				
	Eels	Fish	Molluscs	Crustacea	Algae
Arsenic (4)	NE	2 (1)	1 (1)	2 (1)	1 (1)
Cadmium	0.1 (2)	0.05 (2)	1 (2) (2 (3))	0.5 (2)	NE
Lead	0.3 (2)	0.3 (2), (3)	1.5 (2)	0.5 (2)	NE
Mercury (6)	1 (1), (2), (3)	0.5 (1), (2), (3) 1 (1), (7)	0.5 (1)	0.5 (1)	NE
Copper	NE	2 (5)	30 (5)	20 (5)	NE
Selenium	NE	2 (5)	1 (5)	1 (5)	NE
Zinc	NE	15 (5)	290 (5)	40 (5)	NE

Notes: All results and guidelines in units of mg/kg, wet weight.

Italicised bolded text *indicates exceedance of adopted criteria*

NE not established.

1. *FSANZ (2011)*
2. *EC (2010)*
3. *WHO (2011)*
4. *Criteria based on inorganic arsenic*
5. *FSANZ (2001). Generally Expected Levels (GELs) for Metal Contaminants – Additional guidelines to Max levels in Standard 1.4.1 – Contaminants and Natural Toxicants. The guidelines are given for median and 90th percentile values however only the 90th percentile value is presented on the basis the guidelines recommend that exceedance of the 90th percentile value should initiate further investigation into the source of the concentration.*
6. *Mercury is assumed to be in the organic form of methylmercury for all aquatic biota.*
7. *Relevant for mean concentrations in predatory fish only.*

7.1.6.1 Marine biota

Marine biota data was obtained from three sources:

- Deep slope survey. This survey was undertaken to determine the types of fish located in the region of the proposed DSTP. The survey characterised species composition and prevalence of the deep-slope and pelagic fish fauna of the upper Huon Gulf and included the Markham Canyon, shelf waters off Labu Lakes and Benalla Banks. The characterisation of the fish and locations surveyed are detailed in the deep-slope and pelagic fish characterisation study (Coffey, 2018b).
- Fish market data. Fish purchased from the Department of Civil Aviation (DCA) Point market were sampled and analysed for metals. Locally available fish and fish identified in the deep-slope survey were also compared to determine the availability of such fish for consumption by populations in Study Area 3 and Study Area 4, in conjunction with anecdotal evidence with local villages in each study area. The results of the market fish survey and subsequent observations are detailed in the deep-slope and pelagic fish characterisation study (Coffey, 2018b).
- Market basket survey. A market basket survey undertaken included the assessment of fish, molluscs and prawns in Labu 1 and Labu 3 (assumed to be Labu Butu and Labu Tale respectively), within Study Area 3. The methodology and results of the survey are summarised in section 7.1.7.1 and detailed in the draft Market Basket Food Contaminant Study (Bentley, 2011). Whilst the data collected for the Market Basket study was obtained several years ago, villagers are likely to be consuming the same types of foods as conditions in Study Areas 1 and 3 have not undergone major demographic, environmental or economic change. The concentrations of metals in foods are unlikely to have changed significantly over this period however further data should be obtained closer to construction to confirm baseline conditions for foods, particularly terrestrial and aquatic plants not sampled in the more recent studies, or where data sets are considered small or are left censored with relatively high laboratory limits of reporting (refer to Section 8.3.7.1).

Deep-slope biota (bony fish and sharks)

Deep-slope and surface pelagic fishing surveys were undertaken by Marscco and Coffey staff from 3-13 November 2016 (90 fishing hours), and by Marscco and WGJV staff from 4-10 May 2017 (56 fishing hours).

Sixty-one individuals of eight species from five families were caught over the DSTP Study Area and the reference study area, none of which were pelagic fish species.

Families identified comprised two elasmobranch families, namely Centrophoridae (gulper sharks, three species) and Squalidae (dogfishes, one species), and three bony fish families, namely Lutjanidae (snappers, two species), Sciaenidae (drummers, one species) and Muraenesocidae (pike eels, one species). Locals at Wagang village indicated that the dwarf gulper shark is not commonly caught nor targeted to be sold or for consumption.

Fish market data (bony fish and sharks)

Fourteen bony fishes were sourced from the DCA Point fish market in Lae during November 2016 to complement species diversity recorded in the DSTP and reference study areas. All species observed at the DCA Point fish market were reportedly captured within the upper 100m of the water column, and in coastal areas south of Lae, typically outside the influence of noticeable sediment plumes derived from the Markham River. Discussions were held with local fishers at the market to determine the locations and approximate depths of where the purchased fish were caught.

The bony fish comprised five species from two families, Lutjanidae (snappers, mangrove jacks) and Carangidae (trevallies, mackerels). In terms of numbers, 9 of the 14 specimens were lutjanids normally found in coastal areas with offshore reefs (e.g., *Pristipomoides typus* and *L. malabaricus*), or areas associated with coastal lagoon/lake environments (*L. argentimaculatus*).

Species caught by local fishers and sold at the DCA Point fish market were identified as being seasonally variable and include mackerel (often used as bait), saddletail snapper, sharptooth jobfish, emperors and various reef fishes. Captured pelagic species include rainbow runner, bigeye trevally and tuna. Several other species were also observed for sale at the street market including grouper, triggerfish, snake eel, whitecheek sharks and barracuda.

No fish were sourced from the DCA Point fish market during the field studies in May 2017. However, three visits were made to the market to ascertain species diversity on those particular occasions.

Nearshore marine biota

Nearshore marine biota were not sampled for the baseline evaluation as it is considered unlikely the metal contaminants present in the DSTP area will have any significant impact on nearshore biota. Whilst villagers in Study Area 4 generally catch and collect shellfish and prawns from freshwater or estuarine habitats and only occasionally go fishing from the shoreline using handlines, the villagers in Study Area 3 are known to use the nearshore areas for collecting seafood.

The Market Basket survey undertaken in 2011 (Bentley, 2011) collected a number of aquatic food samples for metal analysis. Whilst the survey did not detail the areas where food was collected, it is likely the foods were sourced in the mangroves or marine waters as many are noted to own boats. On this basis, the results of food sampled at Labu 1 (located near the mouth of the Markham River) and Labu 3 (situated on the western coastline of Huon Gulf) in the Market Basket survey are compared to the aquatic food criteria in Table 7.11.

7.1.6.2 Baseline assessment – marine biota

The mean concentration of toxic metals found in marine water foods are compared to the aquatic food criteria in Table 7.11.

Table 7.11: Marine food screening assessment [mg/kg]

Compound	Screening Criteria & Mean Biota Concentrations		Marine – Aquatic Biota			
			Eels	Fish	Molluscs	Crustacea
Arsenic (4)	Screening Criteria (5)		NE	2 (1)	1 (1)	2 (1)
	Mean Concentration (7)	Marine: Deep slope (6)	3.2	1.6	NA	NA
		Marine: Lae Market	NA	0.03	NA	NA
		Market Basket (8)	NA	0.09	0.09	0.01
Cadmium	Screening Criteria		0.1 (2)	0.05 (2)	1 (2) (2 (3))	0.5 (2)
	Mean Concentration	Marine: Deep slope (6)	<0.05	<0.05	NA	NA
		Marine: Lae Market	NA	<0.05	NA	NA
		Market Basket (8)	NA	0.01	0.13	0.02
Lead	Screening Criteria		0.3 (2)	0.3 (2), (3)	1.5 (2)	0.5 (2)
	Mean Concentration	Marine: Deep slope (6)	<0.01	<0.1	NA	NA
		Marine: Lae Market	NA	<0.1	NA	NA
		Market Basket (8)	NA	0.025	0.33	0.03
Mercury	Screening Criteria		1 (1), (2), (3)	0.5 (1), (2), (3) 1 (1), (9)	0.5 (1)	0.5 (1)
	Mean Concentration	Marine: Deep slope (6)	0.24	***0.62*** 0.69 (9)	NA	NA
		Marine: Lae Market	NA	0.29	NA	NA
		Market Basket (8)	NA	0.12	0.063	0.006

Compound	Screening Criteria & Mean Biota Concentrations		Marine – Aquatic Biota			
			Eels	Fish	Molluscs	Crustacea
Copper	Screening Criteria		NE	2 (5)	30 (5)	20 (5)
	Mean Concentration	Marine: Deep slope (6)	0.1	0.27	NA	NA
		Marine: Lae Market	NA	0.23	NA	NA
		Market Basket (8)	NA	0.27	16	9.2
Selenium	Screening Criteria		NE	2 (5)	1 (5)	1 (5)
	Mean Concentration	Marine: Deep slope (6)	<0.5	0.57	NA	NA
		Marine: Lae Market	NA	0.6	NA	NA
		Market Basket (8)	NA	0.49	0.63	0.58
Zinc	Screening Criteria		NE	15 (5)	290 (5)	40 (5)
	Mean Concentration	Marine: Deep slope (6)	2.6	2.77	NA	NA
		Marine: Lae Market	3	3.09	NA	NA
		Market Basket (8)	NA	9.14	127	17

Notes: All results and guidelines in units of mg/kg, wet weight.
NA samples not available
NE not established
Italicised bolded text indicates exceedance of adopted criteria

1. *FSANZ (2011)*
2. *EC (2010)*
3. *WHO (2011)*
4. *Criteria based on inorganic arsenic. The average concentrations reported in fish have therefore been adjusted by 10% on the assumption the total arsenic measured is generally found to comprise only 10% inorganic arsenic.*
5. *FSANZ (2001). Generally Expected Levels (GELs) for Metal Contaminants – Additional guidelines to Max levels in Standard 1.4.1 – Contaminants and Natural Toxicants. The guidelines are given for median and 90th percentile values however only the 90th percentile value is presented on the basis the guidelines recommend that exceedance of the 90th percentile value should initiate further investigation into the source of the concentration.*
6. *Deep-slope marine biota – fin fish shark and eel from the 2016 and 2017 surveys.*
7. *The measured total arsenic concentration has been conservatively adjusted by 10% to account for the inorganic arsenic content to allow comparison with the inorganic arsenic screening criteria.*
8. *Labu 1 and Labu 3. Bentley (2011)*
9. *Relating to predatory fish only, such as Dwarf Gulper shark (predominately caught in the deep-slope survey).*

Whilst the average mercury concentration in the deep-slope bony fish exceeded the screening criteria adopted for bony fish, the gulper shark was the main species caught and the average mercury concentration was below the screening criteria adopted for predatory fish. All other contaminants in market fish and in the market basket survey were below the adopted screening criteria.

7.1.6.3 Freshwater biota

A number of investigations of metals in biota from waterways in Study Area 1 have been undertaken however not all the data is available in a form that can be utilised for this assessment. The most recent study undertaken in 2015 by BMT WBM (2016) is considered to be consistent with their earlier investigation in 2012 and therefore has been used. Two studies have been utilised for the baseline assessment as follows:

- Fish and prawn sampling was undertaken at four locations associated with the Lower Watut River, its floodplains and tributaries in 2015 (BMT WBM, 2016). The biota sampling undertaken in this investigation is considered to be generally representative of freshwater foods collected by populations in Study Area 1 (Tier 2).

- Market Basket Contaminant Survey of the Watut-Markham Rivers – draft report. A market basket survey was undertaken by Dr Keith Bentley for the Hidden Valley Gold Mine located upstream of the Project, on the Upper Watut River in the Morobe Province. The survey included the assessment of freshwater fish, molluscs and prawns in downstream villages including in those on the Lower Watut River. Madzim, Gingen, Wampan and Uruf were included in the survey and are within Study Area 1. The methodology and results of the survey are summarised in Section 7.1.7.1 and detailed in the draft Market Basket Food Contaminant Study (Bentley, 2011).

7.1.6.4 Baseline assessment – freshwater aquatic foods

The mean concentration of toxic metals found in freshwater and marine water foods are compared to the aquatic food criteria in Table 7.12.

Table 7.12: Freshwater aquatic foods – screening assessment [mg/kg]

Compound	Screening Criteria & Mean Biota Concentrations		Aquatic Biota		
			Fish	Molluscs	Crustacea
Arsenic (4)	Screening Criteria (5)		2 (1)	1 (1)	2 (1)
	Mean Concentration (6)	Fresh-water	0.009	NA	0.03
		Market Basket	0.007	0.053	0.008
Cadmium	Screening Criteria		0.05 (2)	1 (2) (2 (3))	0.5 (2)
	Mean Concentration	Fresh-water	0.007	NA	0.08
		Market Basket	0.01	0.05	0.03
Lead	Screening Criteria		0.3 (2), (3)	1.5 (2)	0.5 (2)
	Mean Concentration	Fresh-water	0.02	NA	0.09
		Market Basket	0.03	0.06	0.03
Mercury	Screening Criteria		0.5 (1), (2), (3)	0.5 (1)	0.5 (1)
	Mean Concentration	Fresh-water	0.06	NA	0.02
		Market Basket	0.29	0.02	0.08
Copper	Screening Criteria		2 (5)	30 (5)	20 (5)
	Mean Concentration	Fresh-water	0.42	NA	34.6
		Market Basket	0.44	1.59	10.23
Selenium	Screening Criteria		2 (5)	1 (5)	1 (5)
	Mean Concentration	Fresh-water	0.42	NA	0.33
		Market Basket	0.41	0.27	0.55
Zinc	Screening Criteria		15 (5)	290 (5)	40 (5)
	Mean Concentration	Fresh-water	***22.7***	NA	28.3
		Market Basket	***17.8***	60.4	21.4

Notes: All results and guidelines in units of mg/kg, wet weight.
NA samples not available
NE not established
Italicised bolded text indicates exceedance of adopted criteria

1 *FSANZ (2011)*
2 *EC (2010)*
3 *WHO (2011)*
4 *Criteria based on inorganic arsenic*
5 *FSANZ (2001). Generally Expected Levels (GELs) for Metal Contaminants – Additional guidelines to Max levels in Standard 1.4.1 – Contaminants and Natural Toxicants. The guidelines are given for median and 90th percentile values*

however only the 90th percentile value is presented on the basis the guidelines recommend that exceedance of the 90th percentile value should initiate further investigation into the source of the concentration.

6 *The measured total arsenic concentration has been conservatively adjusted by 10% to account for the inorganic arsenic content to allow comparison with the inorganic arsenic screening criteria.*

The average concentrations of zinc in fish exceeded the adopted screening criteria in both the 2015 investigation (BMT WBM, 2016) and the 2011 market basket survey of Study Area 1 (includes both Tier 1 and Tier 2 sample locations). All other average contaminant concentrations were below the adopted screening criteria in both surveys.

7.1.7 Terrestrial biota

7.1.7.1 Baseline data – Terrestrial foods

The draft Market Basket Food Contaminant Survey of the Watut-Markham Rivers (Bentley, 2011) report presents the results of sampling (n=347) and testing 28 food types commonly consumed by local communities for a selection of metal contaminants. The food sampling was conducted in 17 villages along the Upper, Middle and Lower Watut and Markham rivers and between the river system and the Huon Gulf.

The villages of interest for the HHRA include:

- Madzim and Gingen villages, located within Tier 1 of Study Area 1.
- Villages Wampan and Uruf, within Tier 2 of Study Area 1, located along the Lower Watut River.
- Labu 1, (Labu Butu), located near the mouth of Markham River and the Huon Gulf within Study Area 3 and Labu 3 (assumed to be Labu Tale), located further south on the coast of the Huon Gulf.

The collection of foods for sampling was carried out at the traditional markets, local village home producers and fishing and bush-food-gathering sites. Three samples of each food product, each sample sufficient to feed three adults, was randomly collected or purchased. The food items were selected based on what was considered to be representative of the principal food groups as well as foods that were known to bioaccumulate particular metals.

Not all of the selected foods were available from all locations at the time of the survey as a consequence of the local circumstances, seasonal food availability and the presence of the particular food in the local diet. The mean concentration of selected metals found in plant foods grown or collected in Study Area 1 and Study Area 3 are compared to the adopted screening criteria for each plant food group in Table 7.13.

Table 7.13: Terrestrial plant food screening assessment [mg/kg]

Compound	Study Area	Location	Plant Foods [mg/kg]					
			Root & tuber vegetables	Leafy vegetables	Legumes	Fruiting vegetables (excluding cucurbits)	Fruiting vegetables – Cucurbits	Fruits
Arsenic (3)	Screening Criteria		Not established					
	Study Area 1	Tier 1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		Tier 2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Study Area 3	Labu 1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		Labu 3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Compound	Study Area	Location	Plant Foods [mg/kg]					
			Root & tuber vegetables	Leafy vegetables	Legumes	Fruiting vegetables (excluding cucurbits)	Fruiting vegetables – Cucurbits	Fruits
Cadmium	**Screening Criteria**		**0.1** [1,2]	**0.2** [1,2]	**0.1** [1]	**0.05** [1]	**0.05** [1]	**NE**
	Study Area 1	Tier 1	0.01	<0.01	0.01	<0.01	<0.01	0.006
		Tier 2	0.02	0.01	0.02	<0.01	0.01	0.01
	Study Area 3	Labu 1	0.01	0.006	0.01	<0.01	0.006	<0.01
		Labu 3	0.02	0.01	0.02	<0.01	0.01	0.006
Copper	**Screening Criteria**		**Not established**					
	Study Area 1	Tier 1	3.56	1.38	3.56	0.62	1.38	1.98
		Tier 2	3.87	1.45	3.87	0.71	1.45	1.95
	Study Area 3	Labu 1	4.99	1.30	4.99	1.02	1.30	1.87
		Labu 3	2.18	1.36	2.18	1.01	1.36	1.79
Lead	**Screening Criteria**		**0.1** [1,2]	**0.3** [1,2]	**0.2** [1,2]	**0.1** [1]	**0.1** [1]	**0.1** [1,2]
	Study Area 1	Tier 1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		Tier 2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Study Area 3	Labu 1	<0.05	0.03	<0.05	<0.05	0.03	<0.05
		Labu 3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	**Screening Criteria**		**Not established**					
	Study Area 1	Tier 1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		Tier 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Study Area 3	Labu 1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		Labu 3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	**Screening Criteria**		**Not established**					
	Study Area 1	Tier 1	<0.05	<0.05	<0.05	<0.05	<0.05	0.046
		Tier 2	0.320	0.045	0.320	0.125	0.045	0.086
	Study Area 3	Labu 1	0.139	<0.05	0.139	<0.05	<0.05	<0.05
		Labu 3	<0.05	0.046	<0.05	<0.05	0.046	0.028
Zinc	**Screening Criteria**		**Not established**					
	Study Area 1	Tier 1	13.8	6.1	13.8	9.4	6.1	10.2
		Tier 2	15.4	5.7	15.4	9.8	5.7	3.6
	Study Area 3	Labu 1	10.5	5.3	10.5	9.6	5.3	3.0
		Labu 3	10.1	7.6	10.1	7.7	7.6	3.2

Notes: All guidelines in units of mg/kg, wet weight.
NA not analysed
NE not established
Italicised bolded text indicates exceedance of adopted criteria

1. *WHO (2011)*
2. *EC (2010)*
3. *Concentrations not adjusted for inorganic arsenic.*

Of the metals analysed in the market basket investigation of plant based foods, only mercury was not detected above the LOR in any samples. None of the average concentrations of metals analysed for each plant food group exceeded the adopted screening criteria in Study Area 1 or Study Area 3.

The market basket survey included sampling of livestock and wild animals consumed in each of the study areas. Samples of fresh foods were obtained from traditional markets, local village home producers and fishing and bush-food-gathering sites. The food preparation methods adopted were based on those published in the Codex Commission Guidelines (FAO/WHO 2006). The Tier 1 screening assessment of the animal meats sampled is presented in Table 7.14.

Table 7.14: Terrestrial animal food screening assessment [mg/kg]

Compound	Study Area	Location	Animal Foods [mg/kg]				
			Meat: Bovine animals (1)	Offal: Bovine animals (1	Meat: Reptiles	Meat: Turtle	Meat: wild Birds
Arsenic (4)	**Screening Criteria**		**Not established**				
	Study Area 1	Tier 1	<0.05	<0.05	NA	0.14	<0.05
		Tier 2	0.05	0.06	<0.05	0.06	<0.05
	Study Area 3	Labu 1	0.03	<0.05	<0.05	NA	<0.05
		Labu 3	0.03	<0.05	NA	0.06	<0.05
Cadmium	**Screening Criteria**		**0.05 (2)**	**0.05 (1,2)**	**NE**	**NE**	**NE**
	Study Area 1	Tier 1	<0.01	<0.01	NA	<0.01	<0.01
		Tier 2	<0.01	0.008	<0.01	0.008	<0.01
	Study Area 3	Labu 1	<0.01	<0.01	<0.01	NA	<0.01
		Labu 3	<0.01	0.01	NA	<0.01	<0.01
Copper	**Screening Criteria**		**Not established**				
	Study Area 1	Tier 1	0.98	0.98	NA	1.1	1.2
		Tier 2	1.1	1.1	0.76	1.01	2.3
	Study Area 3	Labu 1	1.0	1.4	1.0	NA	4.1
		Labu 3	1.0	1.1	NA	0.87	1.4
Lead	**Screening Criteria**		**0.1 (1,2)**	**0.5 (1,2)**	**NE**	**NE**	**NE**
	Study Area 1	Tier 1	<0.05	<0.05	NA	<0.05	<0.05
		Tier 2	<0.05	0.04	<0.05	<0.05	<0.05
	Study Area 3	Labu 1	<0.05	<0.05	<0.05	NA	<0.05
		Labu 3	<0.05	<0.05	NA	<0.05	<0.05

Compound	Study Area	Location	Animal Foods [mg/kg]				
			Meat: Bovine animals [(1)]	Offal: Bovine animals [(1]	Meat: Reptiles	Meat: Turtle	Meat: wild Birds
Mercury	**Screening Criteria**		**Not established**				
	Study Area 1	Tier 1	0.02	<0.01	NA	0.09	0.01
		Tier 2	0.03	<0.01	0.02	0.04	<0.01
	Study Area 3	Labu 1	0.02	<0.01	0.01	NA	0.12
		Labu 3	0.05	<0.01	NA	0.02	0.01
Selenium	**Screening Criteria**		**Not established**				
	Study Area 1	Tier 1	0.2	0.58	NA	0.32	0.13
		Tier 2	1.04	0.26	1	0.59	0.36
	Study Area 3	Labu 1	0.35	0.42	0.13	NA	0.34
		Labu 3	0.44	0.37	NA	0.4	0.29
Zinc	**Screening Criteria**		**Not established**				
	Study Area 1	Tier 1	18.7	17	NA	39	18
		Tier 2	23	19.5	26	38	26.5
	Study Area 3	Labu 1	27	16.6	42	NA	14
		Labu 3	33	19.4	NA	37	42

Notes: All guidelines in units of mg/kg, wet weight.
NA not analysed
NE not established
Italicised bolded text indicates exceedance of adopted criteria

1. *Bovine animals include sheep, pig & poultry.*
2. *WHO (2011)*
3. *EC (2010)*
4. *Concentrations not adjusted for inorganic arsenic.*

No exceedances were noted in terrestrial foods sampled in the market basket survey.

7.2 Biological specimen analysis

A public health and biomedical survey was conducted by Abt JTA in 2013 which included the collection of biological specimens for metal analysis from villagers located within Study Area 1 and Study Area 3. Seven villages were selected for the study within Study Area 1 (Gingen, Hekeng, Madzim, Pekumbe, Timini, Uruf and Zilani). Whilst villages in the Coastal Area, Labu 1 and Labu 2 were considered to be representative of Study Area 3 and possibly Study Area 4, it should be noted they may not reflect residents of Lae who are also within Study Area 3 due to likely differences in their sources of food.

Samples of whole blood, urine and hair were analysed for a limited number of metals and metalloids.

7.2.1 Screening criteria – biological specimens

The adopted screening criteria for this HHRA are consistent with the survey report (Abt JTA, 2013) as the raw data set was not provided for comparison with more recent screening criteria however this is noted where relevant. The screening criteria for whole blood, urine and hair are presented in Table 7.15.

Table 7.15: Biological specimen screening criteria

Specimen Type	Units	Arsenic	Cadmium	Lead	Mercury	Selenium
Whole blood	µg/L	-	5	100 (1)	10	1000
Urine	µg/g of creatinine	-	5	-	20	-
	µg/L	100	-		-	
Hair	µg/g	-	-	-	2	-

– Biological samples were not collected or not analysed for this chemical.

1. *Blood lead levels above 50 µg/L are now considered a trigger requiring further investigation of the potential health risk to children by health or environmental agencies in Australia and the U.S.A (NHMRC, 2015 and CDC, 2012).*

7.2.2 Baseline assessment – biological specimens

Table 7.16 summarises the field based specimen tests undertaken for blood lead testing, as well as laboratory tests of venous blood, although it is not clear whether both tests were undertaken for all subjects. The results of tests were provided as an average for each village. The results for lead and mercury measured in whole blood and arsenic in urine, the number of people and the percentage exceeding the screening criteria were also presented.

Table 7.16: Biological specimen – Tier 1 (T1) screening assessment

Chemical	Study Area	Location	Specimen Type			
			Whole blood	Urine		Hair
			µg/L	µg/g of creatinine	µg/L	µg/g
Arsenic	Screening Criteria		-	-	100 (1)	-
	Study Area 1	Tier 1	NA	NA	***20 – 30% people surveyed exceeded (2)***	NA
		Tier 2			***12 – 43% people surveyed exceeded***	
	Study Area 3	Labu 1			***79% people surveyed exceeded***	
		Labu 2			***51% people surveyed exceeded***	
Cadmium (3)	Screening Criteria		5	5	-	2
	Study Area 1	Tier 1	0 – 0.56	0 – 0.05	NA	NA
		Tier 2	0 – 0.07	0 – 0.05		
	Study Area 3	Labu 1	0	0.2		
		Labu 2	0.06	0.03		
Lead	Screening Criteria		100 (1)	-	-	-
	Study Area 1	Tier 1	No exceedances	NA	NA	NA
		Tier 2	No exceedances			
	Study Area 3	Labu 1	11% people surveyed exceeded (4)			
		Labu 2	No exceedances			
Mercury (3)	Screening Criteria		10	20	Not established	2
	Study Area 1	Tier 1	No exceedances	0.2 – 1.1	NA	0.3 – 0.8
		Tier 2	No exceedances	0.5 – 2.2		0.5 – 0.7

Chemical	**Study Area**	**Location**	**Specimen Type**			
			Whole blood	**Urine**		**Hair**
			µg/L	**µg/g of creatinine**	**µg/L**	**µg/g**
	Study Area 3	Labu 1	17% people surveyed exceeded	0.5		0.6
		Labu 2	No exceedances	0.7		1.1
Selenium (3)	**Screening Criteria**		**1000**	**-**	**-**	**-**
	Study Area 1	Tier 1	124 – 269	NA	NA	NA
		Tier 2	237 – 436			
	Study Area 3	Labu 1	208			
		Labu 2	280			

– Biological samples were not collected for this chemical.

NA – not analysed

Italicised bolded text indicates exceedance of adopted criteria

1. *Blood lead levels less than 50 µg/L are now considered unlikely to pose a potential health risk to children by health or environmental agencies in Australia and the U.S.*
2. *Zilani did not report any exceedances however it is noted the village is located south east of the Mine Area.*
3. *Average concentrations.*
4. *Capillary samples from adults and children >6years.*

Exceedances of blood lead and mercury was reported at Labu 1 located in the vicinity of Study Area 3. The elevated levels of these metals in blood in some villagers are likely to be due to the high consumption of fish and shellfish. Whilst the exceedances of blood lead relate to capillary blood tests conducted in the field, the mean concentrations in venous blood did not exceed the adopted criteria. It is not known if any individuals' blood lead levels exceeded the lower screening criteria of 50µg/L recently adopted in some countries. Arsenic levels in urine were exceeded in Study Area 1 and Study Area 2 with the exception of Zilani which is located near the south east of Study Area 1, and were also noted to potentially be related to high levels of fish consumption by some villagers.

7.3 Tier 1 (T1) summary and data uncertainties

The outcomes of the Tier 1 (T1) screening assessment are summarised in Table 7.17.

Based on the available data, the Tier 1 baseline assessment indicates communities living in villages located within Study Areas 1, 3 and 4 are likely to be exposed to levels of contaminants below health based guidelines in air, drinking water, surface water and terrestrial plants and meats. Freshwater fish and deep sea fish exceeded screening criteria for zinc and mercury, respectively.

Although a relatively conservative approach has been adopted, the uncertainties regarding the adequacy and quality of the data set and potential data gaps should be taken into account when considering the conclusions of the Tier 1 baseline evaluation. Where uncertainties or data gaps are noted in Table 7.17, additional data collection will be undertaken prior to the commencement of construction, to refine the outcomes of this HHRA.

Table 7.17: Summary Tier 1 (T1) evaluation and uncertainties

Media	Study Area	Data availability	Uncertainties	Importance Data gap refinement	Exceedances of screening criteria
Air	Study Area 1	Baseline PM_{10} and dust deposition data collected in 2011 and 2013-2015 respectively.	Based on SLR (2012) baseline data from four villages in Study Area (Tier 1) were assessed for PM_{10} (one sample collected in May 2011) and dust (6 monthly samples collected in the dry season between Jun – Nov 2011). Information relating to potential activities by villages that may assist in understanding the variations in dust levels reported at different villages and in different months. Other locations in Study Areas 3 and 4 not included. Other analytes such as metals, NO_x, CO, CO_2, and SO_2 not included.	Low – Medium Collection of information relating to causes of variations in dust levels at selected locations. Collection of baseline air monitoring in Study Area 3.	No exceedances noted
	Study Area 3	Not collected due to presence of industry and activities at the Port of Lae.			-
	Study Area 4	Not collected.			-
Soil	Study Area 1 Tier 1 villages	Soil data from village gardens not available.	Metals in plant biota not available therefore baseline levels of metals in soil on crops evaluated based on Lower Watut River sediment data.	Low - Medium Undertake co-located soil / crop sampling to confirm concentrations in edible plant portions. See terrestrial foods.	None based on Lower Watut River sediment data.
	Tier 2 villages	Soil data from floodplains used for agricultural crop/gardens not available.			
	Study Area 3	Soil data not required for these study areas.	-	-	-
	Study Area 4				
Drinking water	Study Area 1 Tier 1 villages	Drinking water data obtained at the point of exposure.	Only one investigation conducted. Dry season only.	Medium Wet and dry season data required to address seasonal variations at primary, secondary and recreational water sources.	None

Media	Study Area	Data availability	Uncertainties	Importance Data gap refinement	Exceedances of screening criteria
	Tier 2 villages	Drinking water data not obtained at the point of exposure therefore surface water data from Lower Watut River and catchment rivers utilised (also refer to surface water discussion below).	A number of villages along Lower Watut River were reported to use the river water as a secondary drinking water source, with the possibility of being used as a primary source as not specifically stated for most villages. Data at the point of exposure during wet and dry season conditions not known. Additional uncertainties regarding WGJV surface water data set [(1)] and limited BMT WBM investigation data (also refer to surface water discussion below).	Medium – High Wet and dry season data required to address seasonal variations at primary, secondary and recreational water sources.	No adopted concentrations of metals in riverine surface waters exceeded drinking water criteria.
	Study Area 3 Study Area 4	Drinking water data not collected.	Contribution of metals via ingestion of drinking water to overall intake not evaluated.	Low Metal levels assumed to be low if sourced from rainwater tanks or treated city water supply.	-
Surface water	Freshwater Study Area 1	Surface water data from Lower Watut River and catchment rivers utilised. Data predominantly represent dry season conditions.	There are a number of issues with the available data set as provided: BMT WBM 2017 investigations. Tabulated data and methodology not provided. WGJV total metal data was provided however very difficult to interpret as excel spreadsheets only included location ID. Absence of information regarding collection date, LOR, units and non-detects. Data included numerous ‘zero’ concentrations. It is not clear whether the detection limits are lower than the screening criteria.	High Most of the data was not provided in a form to adequately provide confidence in the Tier 1 (T1) baseline assessment. Additional data collection (as per drinking water) and review existing data, to validate data adopted.	No adopted concentrations of metals in riverine surface waters exceeded recreation criteria.
	Marine Study Area 3 Study Area 4	Combined nearshore marine data obtained in Study Areas 3 and 4	Data obtained from 1.5m depth. Shallower samples likely to be more representative of exposure concentrations for recreational users.	Low	No exceedances for recreational use noted.

Media	Study Area	Data availability	Uncertainties	Importance Data gap refinement	Exceedances of screening criteria
Aquatic food	Freshwater Study Area 1	Variety of fish and prawns sampled in Lower Watut River in 2015 by BMT WBM. Raw data from BMT WBM fish and prawn sampling (2013) was not available. Market basket survey data for selected villages obtained by Bentley (2011)	Fish varieties consumed by villagers – not confirmed to match those sampled. No information if aquatic plants are consumed by villagers, hence whether data is required. No data representing molluscs. BMT WBM data likely to relate to the Lower Watut River only therefore contaminant levels in other waterways, particularly used by villagers in Tier 1, not known.	Low- Medium Conduct a market basket and dietary survey including freshwater aquatic foods.	Levels of zinc measured in fish in the BMT WBM (2015) and Bentley (2007, 2011) study exceeded screening criteria. Elevated levels of mercury were reported in the deep sea fish survey (Coffey, 2018b), similar to concentrations measured in the Powell et al study.
	Marine Study Area 3 and Study Area 4	Deep slope fish and market fish samples in 2016 surveys by Coffey. Generally, the deep-slope species sampled, dwarf gulper sharks, are not consumed by locals. Nearshore biota foods (fish, mollusc, crustaceans and plants) not sampled. Market basket survey data for selected villages in Study Area 3 obtained by Bentley (2011) Powell and Powell (2000) – mercury only	Metals in nearshore biota collected for food by villagers in both study areas. Baseline contribution of metals from these food sources not known. Labu and Wagang villagers known to consume fish, prawns, crabs, shellfish and turtle meat/eggs however the proportion of each source (freshwater, estuarine or marine) and varieties consumed is not known. No dietary surveys of coastal villages to determine preference for particular fish (both caught or from market).	Medium Conduct a market basket and dietary survey including marine food groups.	Mercury concentrations in deep slope fish exceeded screening criteria (Coffey, 2018b). Mercury concentrations consistent with those measured in the Powell et al study (2000).

Media	Study Area	Data availability	Uncertainties	Importance Data gap refinement	Exceedances of screening criteria
Terrestrial foods	Study Area 1	Limited data based on 2011 Market Basket survey report.	Terrestrial plant foods not sampled particularly those crops that are grown in the floodplains. Contribution of ingestion of local produce not known. Market basket survey information limited to small number of villages and did not address seasonal availability. Terrestrial biota, both farmed and/or wild, were not sampled. Contribution of ingestion of local animals and animal products (i.e., eggs/milk) limited to market basket survey.	Medium Relatively high LOR possibly overestimates calculated mean concentrations where data set is left censored. Conduct a market basket and dietary survey to include village garden crops and other terrestrial foods.	No exceedances of metals in terrestrial foods noted.
	Study Area 3	Limited data based on 2011 Market Basket survey report.	Market basket survey information limited to two villages and did not include Lae, nor address seasonal availability.	Low – Medium Conduct a market basket and dietary survey.	No exceedances of metals in terrestrial foods noted.
	Study Area 4	No data collected.	Contribution of metals via ingestion of terrestrial foods to overall intake not evaluated.	Low – Medium Conduct a market basket and dietary survey.	-

8 Human health – Tier 2 (T2) assessment of baseline conditions

The Tier 2 (T2) assessment was undertaken to quantitatively assess human health for receptors in a baseline setting on the basis that exceedances of the adopted screening criteria were identified in aquatic foods and biological specimens.

8.1 Human health exposure assessment

The assessment of exposures endeavours to estimate the magnitude, frequency, extent and duration of exposure to contaminated media. This process is depicted in Figure 8.1 and involves:

- Identification of complete exposure pathways requiring quantitative evaluation.
- Calculation of a daily intake of each contaminant for each exposure pathway via:
  - Selection of exposure parameters representative of identified receptor populations for each exposure pathway.
  - Determination of the concentration of each contaminant in media at the point of exposure for each exposure pathway.

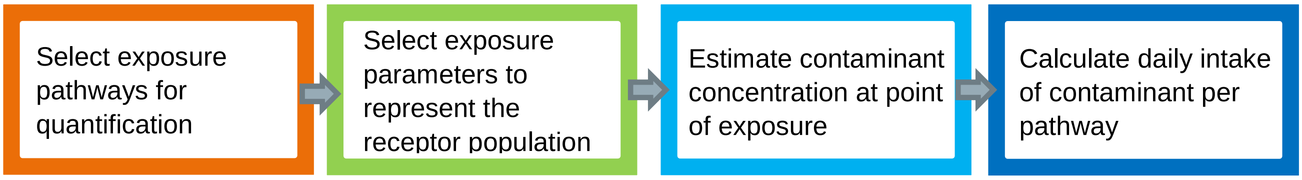


Figure 8.1: Exposure Assessment Process

8.2 Exposure pathway selection

Adults and children in the Study Area 1 villages may be exposed to waterborne contaminants associated with the deposition of contaminants during high rainfall events which result in the flooding of the alluvial floodplains where village food is grown and/or collected. In addition, fish and other aquatic biota may be exposed to metals in the water and take up metals that may be subsequently consumed by people.

It is important to note, however, that during heavy rainfall events, sediment-laden overland flows enter the mine creeks, which will also have elevated flows and naturally high TSS concentrations.

The Socioeconomic Baseline (Coffey, 2018c) reported villages in Study Area 1 are generally subsistence based and grow food for home consumption, indicating the importance of this potential exposure pathway to chemical intake. Garden crops, foraged food and freshwater aquatic biota were frequently consumed by people in the villages.

Village communities in Study Area 3 and Study Area 4 outside of Lae are known to also engage in subsistence activities, such as gardening, fishing, gathering and hunting.

Drinking water is primarily obtained from piped water from nearby waterways (generally located on tributaries of the main rivers in Study Area 1) and extracted groundwater wells. Surveys indicated secondary water sources in Study Area 1 may include creeks or rivers such as the Watut River, however these where not specifically identified. Bathing and washing were also noted to occur in nearby creeks or rivers in Study Area 1. Study Area 3 and Study Area 4 generally relied on reticulated water supply or rainwater tanks for drinking water and domestic uses.

In this HHRA, a preliminary review of the exposure pathway evaluation and the likely fate and transport of metals in water as described earlier in Section 6, and subsequent Tier 1 (T1) screening assessment identified the following exposure scenarios for further quantitative appraisal for the baseline conditions, as presented in Table 8.1.

Table 8.1: Baseline exposure pathways

Receptor	Exposure Pathway
Villagers in Study Area 1	Ingestion of drinking water: • Piped water from nearby creeks or groundwater as the primary water supply in Study Area (Tier 1) villages. • Waterways in Lower Watut River catchments used for primary water supply by Study Area (Tier 2) villages or secondary water supply by Study Area (Tier 1 and Tier 2) villages. • Lower Watut River used for primary water or secondary water supply by Tier 2 villages.
	Dermal contact and incidental ingestion of water while undertaking domestic activities such as bathing, cleaning / washing purposes • Waterways in Lower Watut River catchments. • Lower Watut River water.
	Dermal contact and incidental ingestion of water whilst undertaking recreational activities such as swimming, fishing or wading. • Waterways in Lower Watut River catchments. • Lower Watut River water.
	• Ingestion of freshwater fish from local waterways. • Ingestion of freshwater crustaceans from local waterways.
	• Ingestion of local fruits. • Ingestion of local vegetables, grains, nuts and other plant based food.
	• Ingestion of local livestock and wild animals, including meat and other animal products
	• Inhalation of SO_2 in ambient air at Ziriruk and Fly Camp.
Villagers in Study Area 3	• Dermal contact and incidental ingestion of water whilst undertaking recreational activities such as swimming, fishing or wading.
	• Ingestion of fish from local market, or offshore fishing areas. • Ingestion of crustaceans from nearshore.
	• Ingestion of local fruits. • Ingestion of local vegetables, grains, nuts and other plant based food.
	• Ingestion of local livestock and wild animals, including meat and other animal products (i.e., eggs or milk).
Villagers in Study Area 4	• Dermal contact and incidental ingestion of water whilst undertaking recreational activities such as swimming, fishing or wading.
	• Ingestion of fish from local market, or offshore fishing areas. • Ingestion of crustaceans from nearshore.
	• Ingestion of local fruits. • Ingestion of local vegetables, grains, nuts and other plant based food.
	• Ingestion of local livestock and wild animals, including meat and other animal products.

The inhalation of metal COPCs in particulate matter from soils in floodplain areas is considered to be negligible based on the high moisture content of soils near the river and the activities associated with gardening and the growing of crops in the alluvial floodplains. The toxicity of the COPC within soil particulates via inhalation exposures is considered to be low to negligible compared to exposures via ingestion (NEPM, 2013) and therefore are not evaluated further.

8.3 Estimation of intake dose in humans

To estimate how much of each COPC may enter the body via dermal contact or ingestion of water or food, the exposure assessment selects exposure inputs considered to be representative of the particular receptor population. Whilst the intention of this HHRA is not to calculate exposures for each individual, receptors have been grouped by location and by usual activities undertaken in particular land use settings.

This evaluation assessed the exposures associated with selected metals in water and food using the equations shown below, as defined in NEPM (2013) and:

- Risk Assessment Guidance for Superfund. Vol 1. Human Health Evaluation Manual (Part A). Interim final. EPA/540/1-89/002. Washington. US Environmental Protection Agency. Office of Emergency and Remedial Response.
- Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth, 2012).

Chronic exposures (i.e., exposures that occur over months or years) are calculated rather than acute (short period of time) or intermediate exposures as exposures to the metals that are present in water and foods will occur over a longer period of time, particularly in a village setting. The chronic daily intake (the intake of contaminants over a long period of time) of each contaminant is estimated separately for each identified exposure pathway. The equations used to estimate the chronic daily intake of water and food are presented in Section 8.3.3.

8.3.1 Exposure parameters

The general approach taken for the exposure assessment was to adopt reasonable exposure parameters which are reflective of the typical experiences of the majority of the receptor population, combined with toxicological reference values (refer to Chapter 9) which aim to protect sensitive members of the population. It is acknowledged that human behaviours vary amongst individuals in any setting therefore a more conservative exposure has been evaluated using a mix of both reasonable and upper ranges of exposure inputs to represent average exposures. By adopting such an approach, the calculated intakes are likely to overestimate potential intakes as even the reasonable assessment combines a number of maximum exposure input assumptions.

In order to evaluate typical exposures, average and conservative exposure parameters likely to reflect the lifestyle and activities of the villagers were adopted where available. The exposure parameters adopted for dermal contact and the ingestion and incidental ingestion of water are summarised in Table 8.4, and the parameters adopted for the ingestion of food and soil are summarised in Table 8.4 and Table 8.5. The parameters were generally based on data published by the following sources where site specific information is not available:

- OTML Community Health Study (Bentley, 2007a).
- Market Basket Food Contaminant Survey (Bentley, 2011).
- Environmental Health Standing Committee (enHealth, 2012b).
- National Environment Protection Measure - Assessment of Site Contamination (NEPM, 2013).

Young children are considered to be the most sensitive age group as the relative intake for young children (aged 0 to 5 years) has been demonstrated to differ from older children and adults based on weight to food intake ratios and hygiene behaviours. Consequently, receptors have been split into two age groups as consistent with the NEPM (2013) and FSANZ (2016b) calculations: adults and young children 0 to 5 years. As a conservative approach, the parameters for children were generally selected to represent a child aged 2-3 as they are considered to be the more sensitive group in this age range.

8.3.2 Surrogate data sources

Whilst site specific data is preferred, it has not always been possible to obtain this data for the following reasons:

- Data from previous studies were not available in a suitable form that could be used in this HHRA, or raw data sets that included identifiers such as dates, LORs or units could not be sourced.
- Site specific studies had not been commissioned at the time this HHRA was undertaken.

Where sufficient site-specific information had not yet been collected or was considered insufficient, surrogate data relating to selected exposure parameters was used from the Ok Tedi and Fly River studies (Bentley, 2007). Extensive data was collected from the studies of control and impacted village communities within five defined highland, lowland and estuarine/marine regions in Western Province, Papua New Guinea. The studies included both control and impacted villages that were selected based on their locations in relation to the Ok Tedi Mining operations and their potential to have been impacted by chemicals in local foods that may have been released to the environment as a result of mining related activities.

It is possible that some foods will over-represented and others under-represented given some differences in food sources in the Ok Tedi and proposed Project areas. Some foods will be substituted for others but unless the substitution involves foods with widely divergent contaminant levels it is unlikely to make a significant difference to the intake calculations. Whilst this comparison is considered useful in this HHRA, further data and dietary information in the Project study areas will be undertaken to inform the HHRA review prior to mine construction.

A comparison of the Study Areas identified in this HHRA were assessed against the characteristics of villages in each of the regions defined for the Ok Tedi and Fly River studies to determine which regions were likely to be most representative of the study areas defined in this HHRA.

As a conservative approach both control and impacted regions were considered. The appropriate region reflective of the study areas of interest are presented in Table 8.2.

Table 8.2: Surrogate villages for HHRA Study Areas

HHRA Study Area	Description	Representative Ok Tedi, Fly River Region	Description
Study Area 1 Tier 1	Relatively remote, un-impacted area. Limited access to services. Generally subsistence food sources. Water from creeks, springs used for drinking and washing.	**Region 1** Highland region	Two control (un-impacted) and two impacted villages were selected for Region 1. The villages in these regions are relatively isolated or have variable services. Food sources are generally locally grown or caught.
Study Area 1 Tier 2	Villages located near mine access roads and those villages along the Lower Watut River. Water from creeks, springs, water holes, rainwater and extracted groundwater used for drinking and washing.	**Region 2** Lowland region Situated near the meandering middle Fly River area.	Three control and two impacted villages were selected as combined they are likely to reflect conditions of most villages in this portion of Study Area 1. Food sources are generally locally grown or caught.

HHRA Study Area	Description	Representative Ok Tedi, Fly River Region	Description
Study Area 3	City and Port of Lae and surrounds. Located near Markham River mouth.	**Region 5** Estuarine and coastal	Various access to facilities and the provincial capital city. Located near river mouth and marine waters. Greater access to markets or stores. This region included three impacted villages and two control villages.
Study Area 4	Villages of Wagang and Yanga.		

8.3.3 Estimation of intake dose in humans

This evaluation assessed the exposures associated with metals in water and food using the equations shown in Table 8.3, as defined in the NEPM (2013) and the USEPA Risk Assessment Guidance for Superfund sites (RAGS) (USEPA, 1989) (USEPA, 2004) (USEPA, 2009).

Table 8.3: Equations used to estimate chronic daily intake [(1)]

Direct Contact Pathways – Water		
Equation 1	Dermal contact	$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365\ ^{days}/_{year} \times AT \times BW}$$
Equation 2	Ingestion of drinking water	$$CDI_{DWing} = \frac{C_W \times IR_{DW} \times B_o \times EF \times ED}{365\ ^{days}/_{year} \times AT \times BW}$$
Equation 3	Incidental ingestion of water	$$CDI_{Wing} = \frac{C_W \times IR_W \times B_o \times ET \times EF \times ED}{365\ ^{days}/_{year} \times AT \times BW}$$
Dietary Intake Pathway		
Equation 4	Ingestion	$$CDI_{Food\ type} = \frac{C_{Ftype} \times IR_F \times B_o \times EF \times ED}{365\ ^{days}/_{year} \times AT \times BW}$$

Where:

AR	=	Area of exposed skin	[cm^2]
AT	=	Averaging time = ED for COPCs with a threshold health effect	[years]
Bo	=	Bioavailability via ingestion (expressed as a fraction of 1)	[unitless]
BW	=	Body weight	[kg]
CDIDermal		Chronic daily intake via dermal contact with water	[mg/kg/day]
CDIDWing	=	Chronic daily intake via ingestion of drinking water	[mg/kg/day]
CDIFood type	=	Chronic daily intake via food ingestion	[mg/kg/day]
CDIWing	=	Chronic daily intake via incidental ingestion	[mg/kg/day]
CF1	=	Conversion Factor	[L/cm^3]
CW	=	Chemical concentration in water	[mg/L]

ED	=	Exposure duration	[years]
EF	=	Exposure frequency	[days/year]
ET	=	Exposure time	[hours/day]
IRW	=	Incidental ingestion rate	[L/hour]
IRDW	=	Ingestion rate – drinking water	[L/day]
IRF	=	Food ingestion rate	[μg/kg]
P	=	Permeability coefficient (Chemical specific)	[cm/hr]

1 Relates to exposures that occur over a long period of time i.e. months or years.

8.3.4 Input parameters – ingestion exposures relating to water

Exposure parameters

Exposure parameters for villagers are provided in Table 8.4.

Table 8.4: Exposure parameters – dermal, ingestion and incidental ingestion of water

Exposure Parameters		**Value Adopted**		**Reference**	**Symbol (3)**
		Young Child	**Adult**		
Body Weight [kg]		12	57.4	Young children based on 1-5 years Ok Tedi and Fly River regions (Bentley, 2007)	BW
Exposure frequency [days/year].	Drinking water (Primary source)	365		Maximum possible enHealth (2012a)	EF
	Washing/Bathing activities				
	Recreation activities	150		enHealth (2012a) Data for adults assumed for children also	
	Drinking water (Secondary source)	60		Assumed duration in dry season when the secondary water source may be utilised.	
Exposure time [hours/day].	Washing/bathing/ domestic activities	0.13	0.9	Young child based on 1 bath per day. Adults based on food/drink prep. & cleaning, laundry, grounds & animal care activities. Assumed a third of the activity time respectively was directly associated with water; enHealth (2012a)	ET
	Recreation activities	0.5	1	enHealth (2012a)	
Bioavailability - oral ingestion [unitless]		1		Conservatively assumed to be 100%	B_o
Exposed skin area [cm^2]	Recreation	7545	18,200	Ok Tedi and Fly River regions (Bentley, 2007)	AR
	Washing/bathing				
Water ingestion rate [L/d]	Drinking water	1	2	WHO (2017), enHealth (2012a)	$IR_{water\ or\ drinking\ water}$
	Washing activities	0.025	0.0125	Limited information available - assumed to be half the ingestion rate of swimming. enHealth (2012a)	
	Recreation activities	0.05	0.025	enHealth (2012a)	
Exposure duration [years]		5	65	Based on average lifespan and assumed residency time in the same village	ED
Averaging time [years]		5 (1) 70 (2)	65 (1) 70 (2)	Based on exposure duration.	AT

1 Averaging time for threshold chemicals with a tolerable concentration.

2 Averaging time for non-threshold chemicals with a unit risk, assumed to over a 70 year lifetime.

Food ingestion

The consumption rates for aquatic and terrestrial foods were estimated from the food diaries information collected as part of the unit food consumption survey conducted as part of the Ok Tedi Mine Limited Community Health Study (Bentley, 2007). The food consumption study was conducted in villages in each of the five geographic regions as described in Table 8.2.

In order to determine the chronic daily intake of contaminants in food, the consumption frequency of each food type is required, in addition to the amount consumed. These two inputs are used to estimate the amount of each food group consumed per day. The food frequency survey undertaken by the Centre for Environmental Health (Bentley, 2007) provided an estimate of the usual patterns of consumption for individual foods in villages in each of the regions, and was designed to establish the proportion of the diet that was sourced from village gardens, bush-sourced foods and trade stores.

A unit frequency of consumption survey was also conducted by the Centre for Environmental Health (Bentley, 2007) for two villages in each region. It was noted the survey was constrained by a number of factors:

- Limited households surveyed per region.
- “Snacking” was estimated given food was often consumed in the bush or whilst gardening.
- Measurements were taken at different times of the year at each village therefore seasonal availability was not addressed.

To calculate the ingestion rate of different foods for each Study Area in this assessment the food was grouped into the following food types:

Vegetables/Legumes/ Nuts/Grains	Fruit	Terrestrial meat and animal products	Fish	Crustaceans
Sweet potato	Banana	Pork	Fresh fish	Prawn or shrimps
Cassava	Coconut	Lamb	Smoked fish	
Taro	Other fresh fruits	Chicken	Tinned fish	
Yam		Other meats including turtle and bush meats		
Irish potato		Tinned meat		
Sago		Eggs		
Rice				
Sugar cane				
Peanuts & local nuts				
Aibika and other green vegetables				
Yellow vegetables				

Items such as flour, powdered milk, sugar, bread, cereals and biscuits were assumed to be purchased at trade stores that may not be available in Study Area 1, Study Area 3 and Study Area 4 and as such were excluded.

The average food consumption for each food group was calculated for young children and adults in each study area as represented by the Ok Tedi Mine study regions. This data is presented in Table 8.5.

Table 8.5: Food consumption by Study Area [(1)] and food group [grams/week]

Ok Tedi Study Region	Region 1 and Region 2 (Average)		Region 3		Region 5	
Comparative Study Area	Study Area 1 (Tier 1)		Study Area 1 (Tier 2)		Study Area 3 or Study Area 4	
Food commodity	Age group					
	Child 1-5 years	Adult	Child 1-5 years	Adult	Child 1-5 years	Adult
Fruit	1,299	2,043	2,126	1,959	781	614
Vegetables/Legume/Grains/Nuts	4,450	5,852	4,626	6,354	3,803	3,622
Terrestrial meat/ animal products	352	521	748	935	93	167
Fish	101	190	1,619	2,392	225	580
Crustaceans	29 [(2)]	25 [(2)]	-	-	58	50

1. *Based on data obtained from villages in PNG Ok Tedi and Fly River regions (Bentley, 2007).*
2. *Data was not available therefore half the amount calculated for coast study areas was adopted.*

8.3.5 Selection of Tier 2 (T2) contaminants of potential concern

The selection of COPC in the Tier 2 (T2) assessment are determined by the Tier 1 (T1) evaluation of measured concentrations in baseline media, known chronic human toxicity, presence in biological specimens at elevated levels (Abt JTA, 2013) and potential Project related contaminants. Exceedances of screening criteria noted in Section 7.1 are presented in Table 8.6.

Table 8.6: COPC Selection

	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Zinc	Dust	Particulate Matter	SO_2	NO_2
Tier 1 (T1) Screening Evaluation - Exceedances															
Drinking water (1) (Tier 1)	-	-	-	-	-	-	-	-	-	-	-				
Surface water (2)	-	-	-	-	-	-	-	-	-	-	-				
Surface water (3)	-	-	-	-	-	-	-	-	-	-	-				
Marine water	-	-	-	-	-	-	-	-	-	-	-				
Sediments	-	-	-	-	-	-	-	-	-	-	-				
Marine food: Fish	-	-	-	-	-	-	X (4)	-	-	-	-				
Marine food: Crustaceans/Molluscs	-	-	-	-	-	-	-	-	-	-	-				
Aquatic food: Fish	-	-	-	-	-	-	-	-	-	-	X				
Aquatic food: Crustaceans/Molluscs	-	-	-	-	-	-	-	-	-	-	-				
Fruits	-	-	-	-	-	-	-	-	-	-	-				
Vegetables	-	-	-	-	-	-	-	-	-	-	-				
Terrestrial meats	-	-	-	-	-	-	-	-	-	-	-				
Blood / Urine / Hair Analysis (5)	NA	X	-	NA	NA	X	X	NA	NA	-	NA				
Air quality	NA											-	-	-	-
Project-related contaminants (7)															

	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Zinc	Dust	Particulate Matter	SO_2	NO_2
Higher Toxicity - Chronic Exposures		X	X		X	X	X				X				
Geochemical Abundance Index (6)	X	X				X				X	X				
Air Emissions												-	-	X (8)	-
Selected Contaminants		X				X	X				X			X	

- *Indicates either no exceedances or no screening criteria has been established.*

NA – not analysed

X – An exceedance of the screening criteria or other indicator was noted

1. *Study Area 1 (Tier 1) and groundwater associated with Study Area 1 only.*
2. *Highland sub-catchments of the Lower Watut River (Wafi River, Bavaga River and Waime River). Based on 50th percentile concentrations for WGJV data, and average concentrations estimated from BMT WBM data (2016).*
3. *Lower Watut River and floodplains. Based on 50th percentile concentrations for WGJV data, and average concentrations estimated from BMT WBM data (2016).*
4. *Deep slope fish, excluding predatory species.*
5. *The analysis of blood, urine and hair for the presence of metals and trace elements was undertaken in selected villages in Study Area 1 and Study Area 3. Note elevated levels of lead and mercury relate to Study Area 3.*
6. *Indicates a metal or metalloid has exceed the average crustal abundance in natural soils, which correlates to a Geochemical Abundance Index of >3. KCB (2013)*
7. *Refer to Section 6.3.1.*
8. *Based on predictive modelling outcomes. Refer to Section 12.2.1*

The selection of COPC for quantitative evaluation is detailed as follows:

- Antimony was identified in soils from the Mine Area as being relatively elevated when compared to the average crustal abundance in natural soils. The mean or 50th percentile concentrations of antimony in water, sediment or foods did not exceed any screening criteria in the Tier 1 (T1) assessment. On the basis antimony is not readily absorbed following ingestion or dermal contact it was not considered further.
- Arsenic and lead were not identified as potential contaminants of concern in the Tier 1 (T1) assessment as no exceedances of screening criteria for water, sediment or foods were observed. The Tier 1 (T1) screening evaluation was based on average concentrations of the metals. Arsenic exceedances were noted in fish tissue in the Tetra Tech Bioaccumulation Study (Tetra Tech, 2018a) where the reported concentration ranges were used rather than the average concentration. However as both were noted to have elevated Geochemical Abundance Indices and were measured in the blood or urine of some villagers at levels exceeding the health limits, they were selected as COPC.
- Cadmium, chromium, copper, molybdenum and nickel not did exceed criteria in the Tier 1 (T1) assessment and were not identified as a potentially elevated in the Geochemical Abundance Indices. These metals were not assessed further in this assessment.
- Mercury, assumed to be in organic form, exceeded criteria in fish from the deep slope area of the Huon Gulf. Mercury was measured in blood at levels exceeding the health limit in more than 15% of villagers surveyed in Labu 1 (within Study Area 3) and hence was selected as a COPC.
- Elevated average levels of zinc were measured in freshwater fish. Zinc was also identified as being elevated in relation to the average crustal abundance and therefore selected as a COPC for further evaluation.

8.3.6 Selected baseline COPC concentrations in food and water

The concentration of a contaminant at the point of exposure is a key component in estimating the chronic daily intake for each pathway at each location or setting. The COPC concentrations for each environmental media assessed in the HHRA is based on data obtained within the study areas of interest. Each media and the locations or varieties sampled are presented in Table 8.7.

Table 8.7: Environmental media and description

Environmental Media	Description of locations and samples
Drinking water	Samples include those obtained at the source or at the point of exposure (i.e., at the tap, pump outlet or well) at all villages in Study Area 1 (Tier 1). All drinking water supplies were piped to the village from nearby waterways or extracted from groundwater (Wori). The drinking water concentrations were adopted to assess: • Primary drinking water source Study Area 1 (Tier 1)
Surface water Lower Watut River sub-catchments located in the highland areas of Study Area 1, in vicinity of Tier 1 villages.	Data included samples generally obtained from waterways in the highland areas of Study Area 1. The 50th percentile concentration was used rather than the average for the WGJV data set. Average concentrations were calculated from data obtained in 2015-2016 by BMT WBM (2018a). The selected concentration adopted for the baseline assessment of the following exposure sources was the maximum concentration from WGJV (50th percentile) and BMT WBM (average): • Primary drinking water source - Study Area 1 (Tier 2) • Secondary drinking water source - Study Area 1 (Tier 1) • Water source used for bathing/washing - Study Area 1 (Tier 1) • Water source used for recreational use - Study Area 1 (Tier 1)
Surface water Lower Watut River and floodplain areas of Study	Data included samples generally obtained from the Lower Watut River and floodplain in the lowland areas of Tier 2 villages in Study Area 1. The 50th percentile concentration was used rather than the average for the WGJV data set. Average concentrations were calculated from data by BMT WBM (2018a).

Environmental Media	Description of locations and samples
Area 1 in vicinity of Tier 2 villages.	The selected concentration adopted for the baseline assessment of the following exposure sources was the maximum concentration from WGJV (50th percentile) and BMT WBM (average): • Secondary drinking water source Study Area 1 (Tier 2) • Water source used for bathing/washing Study Area 1 (Tier 2) • Water source used for recreational use - Study Area 1 (Tier 2)
Coastal marine water	Average concentrations of COPCs in marine water obtained from nearshore locations in the vicinity of Study Area 3 and Study Area 4 were adopted for the following exposure scenarios: • Water source used for recreational use - Study Area 3 • Water source used for recreational use - Study Area 4
Freshwater aquatic food	Fish sampling has been conducted in a number of investigations that have included the Lower Watut River and Market Basket Survey of selected villages in Study Area 1. The HHRA relied on sampling undertaken by BMT WBM in 2015 which analysed a wide variety of edible fish and prawns (BMT WBM, 2016). The COPC information contained in the 2011 Market Basket Survey also provided information on fish and prawns that may have been sourced from other local rivers or steams in Study Area 1. The data from both studies was combined to estimate the average concentrations of COPCs adopted for this assessment in the exposure scenarios: • Aquatic biota consumed by villages in Study Area 1
Marine water foods	The deep slope survey of fish in the area proposed for DSTP conducted by Coffey in 2017 was dominated by predator fish such as dwarf gulper sharks that are rarely consumed by local villages in Study Area 3 and Study 4, nor are they found in the markets in Lae or the DCA. Coffey also conducted a market survey and analysed fish purchased at the markets for COPC. COPC analytical data from the Coffey market survey was adopted to assess baseline exposures to receptors who may frequent these markets or catch fish from similar locations: • Aquatic biota (fish) consumed by villages in Study Area 4. Data from the Coffey fish market survey and the 2011 Market Basket survey were combined to calculate the average COPC concentrations adopted for Study Area 3: • Aquatic biota (fish, prawns and molluscs) consumed by villages in Study Area 3. • Receptors that live or work in more urban populations in Study Area 3 are not considered in this assessment as fish and prawns are likely to be sourced from multiple sources including supermarkets.
Fresh fruit	Data specifically related to the study areas of interest in this HHRA is limited to the market basket survey conducted by Bentley in 2011. The average concentrations of COPCs in all fruits sampled in villages within each corresponding study area were adopted for the following exposure scenarios: • Fresh fruit consumed by villages in Study Area 1 (Tier 1). • Fresh fruit consumed by villages in Study Area 1 (Tier 2). • Fresh fruit consumed by villages in Study Area 3 and Study Area 4.

Environmental Media	Description of locations and samples
Vegetables and other terrestrial plant foods	Data specifically related to the study areas of interest in this HHRA is limited to the market basket survey conducted by Bentley in 2011. The average concentrations of COPCs in all vegetables (including nuts and grains) sampled in villages within each corresponding study area were adopted for the following exposure scenarios: • Vegetables and plant related foods consumed by villages in Study Area 1 (Tier 1). • Vegetables and plant related foods consumed by villages in Study Area 1 (Tier 2). • Vegetables and plant related foods consumed by villages in Study Area 3 and Study Area 4.
Terrestrial animal foods	Data specifically related to the study areas of interest in this HHRA is limited to the market basket survey conducted by Bentley in 2011. The average concentrations of COPCs in all terrestrial animal related foods (including meat and offal from livestock or wildlife, and animal products such as eggs or milk) sampled in villages within each corresponding study area were adopted for the following exposure scenarios: • Animals and animal products consumed by villages in Study Area 1 (Tier 1). • Animals and animal products consumed by villages in Study Area 1 (Tier 2). • Animals and animal products consumed by villages in Study Area 3 and Study Area 4.

8.3.7 Concentrations of baseline COPC in media

The data set for each media and study area has been used to calculate the average concentrations for use in exposure evaluations. The exception to this approach is the surface water data collected by WGJV where the 50th percentile concentration was used.

The estimated concentrations in media adopted to calculate the exposure intakes for the various exposure pathways are presented in Table 8.8. The detailed data sets for the media listed in Table 8.8 are presented in Appendix B.

Table 8.8: Baseline media concentrations adopted

Media	Location or biota type	Units	Chemical			
			Arsenic	Lead	Mercury	Zinc
Water						
Drinking water	Study Area 1 (Tier 1)	mg/L	0.0007	0.0007	0.0001	0.005
Surface water	Study Area 1 Lower Watut River Sub-catchments	mg/L	0.0002	0.001	0.0001	0.01
Surface water	Lower Watut River and local floodplain	mg/L	0.0001	0.01	0.0001	0.018
Marine water	Coastal Study Areas 3 and 4	mg/L	0.0016	0.0002	0.00004	0.005

Media	Location or biota type	Units	Chemical			
			Arsenic	Lead	Mercury	Zinc
Foods						
Freshwater aquatic biota	Study Area 1: Fish	mg/kg	0.08	0.02	0.07	22.54
	Study Area 1: Crustaceans	mg/kg	1.05	0.11	0.04	120.9
	Study Area 1: Molluscs	mg/kg	0.23	0.08	0.03	27.2
Marine biota	Study Area 3: Fish	mg/kg	2.26	2.26	2.26	2.26
	Study Area 4: Fish	mg/kg	2.45	0.10	0.29	3.09
	Study Area 3: Crustaceans	mg/kg	1.51	0.14	0.13	90.0
	Study Area 3: Molluscs	mg/kg	0.86	0.33	0.06	127.2
Fruits	Study Area 1 (Tier 1)	mg/kg	0.03	0.03	0.01	10.2
	Study Area 1 (Tier 2)	mg/kg	0.03	0.03	0.01	3.63
	Study Area 3 & Study Area 4	mg/kg	0.03	0.03	0.01	3.17
Vegetables/ grains / nuts	Study Area 1 (Tier 1)	mg/kg	0.03	0.03	0.01	6.04
	Study Area 1 (Tier 2)	mg/kg	0.03	0.03	0.01	0.01
	Study Area 3 & Study Area 4	mg/kg	0.03	0.03	0.01	5.18
Animals and animal products	Study Area 1 (Tier 1)	mg/kg	0.04	0.03	0.03	21.6
	Study Area 1 (Tier 2)	mg/kg	0.05	0.03	0.02	25.6
	Study Area 3 & Study Area 4	mg/kg	0.04	0.03	0.03	32.8

8.3.7.1 Treatment of non–detections – approach and limitations

Samples that reported a concentration below the laboratory limit of reporting are considered to be non-detections. The adoption of a zero concentration for each non-detect sample is likely to underestimate the dietary intake, and similarly the adoption of the LOR concentration is considered to overestimate potential intakes of a contaminant. Therefore, in such instances, half of the LOR concentration was adopted. This is considered to be a reasonable approach (NEPM, 2013) particularly when the LOR is well below the selected screening criteria. The higher the LOR, the higher the estimated non-detect concentration.

Whilst this approach is generally reasonable, data sets which consist of more than 15% non-detect results are likely to be skewed when statistical calculations are applied. Where a data set includes a large number of non-detect contaminant concentration estimations and the LOR is relatively high, the calculated average concentrations can be magnified when a data set is left censored. In other words, the bias is increased where the data set contains a higher proportion of non-detect samples, or a small data set. The impact of bias in left censored data sets with relatively high LORs can be adjusted by simulating probability distributions using statistical software, however the number of samples must be greater than 10.

The data sets for some biota were considered small for statistical purposes (i.e., <8 samples for a study area). Generally, the fruit, vegetable and animal food data sets were considered to be left censored as almost all were reported below the LOR for arsenic, lead and mercury. For data sets where the non-detect samples are below 15%, the adoption of half the LOR is considered satisfactory however larger percentages of non-detections will result in a bias. Alternative statistical methods were not available given the small data sets in this instance.

The data selected from the Market Basket Survey (Bentley, 2011) measured a large number of non-detections for arsenic, mercury, lead and selenium in most foods in most study areas. However, given the relatively high LOR for multiple COPCs, there is a greater potential for the intakes to be overestimated. Many of the data sets available at the time of this HHRA contained less than 10 samples for a particular media in each study area and therefore simulations of probability distributions could not be used.

Surface water data collected by WGJV over the 2006–2016 period did not include information such as units, LOR or which samples were considered to be non-detections. As a result, the data was only used to a limited extent (in combination with the smaller data set collected by BMT WBM (2018a) to minimise the risk of over- or underestimating the intakes.

Whilst the uncertainties in some of the data sets are noted above, WGJV have committed to collecting the data needed to address data gaps prior to the construction of the project. The issues regarding small data sets and high LORs will be included in the assessment of data required to refine the uncertainties and provide confidence in the outcomes of the HHRA.

9 Human health toxicity assessment

Toxicity assessment provides an evaluation of the inherent toxicity of chemicals associated, in this instance, with site contamination. It is a process of determining whether human exposure to a chemical could cause an increase in the incidence of an adverse health condition. It considers:

- The nature of adverse effects related to the exposure.
- The dose-response relationships.
- The weight of evidence for effects such as carcinogenicity.
- The relevance of animal data to humans.

The results of the toxicity assessment are an appreciation of the toxicity of the contaminant and a set of chemical-specific toxicity criteria that are used in the assessment of health risks related to exposures to the contaminant.

9.1 Dose-response assessment

9.1.1 Background

Risk assessments evaluate each contaminant based on the type of health effect a particular chemical has been reliably shown to exhibit in robust epidemiology and laboratory studies. The two classes of health effects are based on dose-response characteristics relating to threshold (non-carcinogenic) effects or non-threshold (carcinogenic) effects.

The threshold value refers to a dose below which deleterious effects are not expected to occur. The threshold dose is based upon biological mechanisms that have the ability to metabolise or excrete a toxin or repair damage up to a certain dose (enHealth, 2012b).

A compound is classified as non-threshold (carcinogenic) based on its mode of action. Compounds that have been demonstrated to cause damage to genetic information (DNA) within a cell, either via mutation, amplification or other means, are considered to be genotoxic. Genotoxic compounds are assumed to be non-threshold compounds on the basis that any exposure to the compound may potentially result in genetic damage.

Some chemicals exhibit both non-threshold (i.e., carcinogenic) and threshold (i.e., non-carcinogenic) health effects and therefore may require the risk assessment to address both endpoints.

9.1.2 Non-threshold classification

A review of the International Agency for Research on Cancer (IARC) and U.S. Environmental Protection Agency (USEPA) cancer classifications and NEPM recommendations for the identified COPCs was conducted. The IARC and USEPA cancer classifications is summarised in Table 9.1.

Table 9.1: Cancer classifications

Chemical	Classification of Carcinogenicity		Comments
	IARC (1)	USEPA (2)	
Arsenic	Group 1 (inorganic) Group 3 (organic)	Group A (inorganic)	Arsenic in an inorganic form is a known carcinogen and elicits non-carcinogenic health effects. Inorganic arsenic has been assessed using a threshold dose response approach protective of carcinogenic effects.

Chemical	Classification of Carcinogenicity		Comments
	IARC (1)	USEPA (2)	
Mercury and inorganic mercury compounds	Group 3	Group D	USEPA identifies that there is inadequate evidence to assess carcinogenicity in animals or humans. Mercury has been assessed based on threshold health effects. It is essential nutrient for humans and aquatic biota.
Methylmercury	Group 2B	Group C	The USEPA has based this finding on inadequate data in humans and limited evidence of carcinogenicity in animals.
Lead	Group 2B	Group B2	Animal studies indicate carcinogenic effects however, the evidence form human studies indicated adverse effects not related to cancer may occur at lower levels. Lead has been assessed based on threshold health effects.
Zinc	NA	Group D	USEPA identifies that there is inadequate evidence to assess carcinogenicity in animals or humans. Zinc has been assessed based on threshold health effects. It is essential nutrient for humans and aquatic biota.

NA = Not Assessed

1 IARC Cancer Classification: Group 1 (carcinogenic to humans), Group 2A (probably carcinogenic to humans), Group 2B (possibly carcinogenic to humans), Group 3 (unclassifiable as to carcinogenicity in humans).

2 USEPA Cancer Classification:

- 1986 Guidelines: Group A (carcinogenic to humans); Group B1 (probable carcinogenic to humans, limited human evidence); Group B2 (probable carcinogenic to humans, sufficient evidence in animals); Group C (possibly carcinogenic to humans); Group D (unclassifiable as to carcinogenicity in humans).

Based on the classifications of carcinogenicity published by IARC and the USEPA, all COPC other than arsenic are considered to have threshold health effects. Arsenic, when in its inorganic form, is known to cause both carcinogenic and non-carcinogenic health effects. Inorganic arsenic has therefore been assessed using a threshold dose response approach which is considered to be protective of potential carcinogenic effects (NEPM, 2013).

9.1.3 Toxicity reference values and chemical specific parameters

The adopted toxicity reference values (TRVs) adopted in this HHRA are developed by international agencies such as the World Health Organization. The TRVs are health based guidance values that indicate the amount of a chemical that a person can be exposed to (via a specific exposure route) on a regular basis without significant risk to health. In this instance the TRVs are selected based on the tolerable daily intake.

The tolerable daily intake is the concentration per kilogram body weight per day that is deemed to pose no adverse health effects over a lifetime of exposure. The toxicological endpoints for the COPCs are represented by a threshold TRV based on no adverse effect levels in human or animal studies and adjusted by a number of safety and uncertainty factors. The toxicity reference values adopted for the COPCs are summarised in Table 9.2 (oral and dermal). Chemical specific information is also presented in this table.

Table 9.2: Toxicity Reference Values for the Contaminants of Potential Concern – direct contact pathways

Chemical	Non-Threshold	Threshold	Gastro-intestinal Absorption Factor (2) [%]	Dermal Absorption Factor (3) [%]	Oral Bio-availability (2) [%]	Skin Permeability Constant (2) [cm/hr]
	Slope Factor $[mg/kg/day]^{-1}$	Tolerable Daily Intake (1) ([mg/kg/day]				
Arsenic (inorganic)	NA	0.002 (3)	100	0.005	100	0.001
Lead	NA	0.0035 (3)	100	0.001	100	0.0001
Mercury	NA	0.0006 (4)	100	0.0001	100	0.001
Methylmercury	NA	0.00023 (7)	100	0.001	100	0.001
Zinc	NA	0.5 (8)	100	0.001	100	0.0006

1. *Note weekly intakes have been converted to a daily intake where relevant.*
2. *RAIS 2018.*
3. *NEPM 2013.*
4. *WHO 2011.*
5. *Based on a JECFA permissible tolerable weekly intake (PTWI), which has since been withdrawn as it was no longer considered protective of health. On the basis no new PTWI has been established and the uncertainties of adopting a blood lead model in this instance, the previous PTWI has been adopted.*
6. *Negligible therefore a dermal absorption factor (DAF) of 0.0005 adopted.*
7. *WHO (2004) and EA (2009).*
8. *NHMRC (2006).*

Mercury is assumed to be in the organic form of methylmercury for the assessment of all aquatic biota. The predicted intake doses for the scenarios based on the adopted exposure parameters and toxicity criteria are presented in Appendix E**.**

10 Risk characterisation

Risk characterisation is the process of quantifying the risks of exposure exceeding the tolerable daily intake (TDI), in order to understand the potential for increased health risks from exposure to a selected contaminant. It involves using the information obtained in the toxicity assessment and the exposure evaluation to calculate the risk.

The risk from threshold chemical exposure is expressed in terms of the Hazard Quotient (HQ). The HQ is the ratio of the estimated exposure in terms of chronic daily intake (CDI), to the tolerable daily intake. The Hazard Quotients are calculated as presented in Table 10.1.

Table 10.1: Equation used to calculate the Hazard Quotient

Threshold Pathways - Direct Contact and Ingestion	
Equation 5 (USEPA, 1989)	$HQ = \frac{CDI}{TDI}$
Where, HQ = Hazard Quotient for a pathway and chemical specific exposure (unitless) CDI = Chronic Daily Intake (mg/kg/day) TDI = Tolerable Daily Intake (mg/kg/day)	

Where HQ is less than 1, there is unlikely to be any adverse health effects associated with exposure to the individual COPC associated with a particular exposure pathway. However, a HQ exceeding 1 does not necessarily indicate an actual risk but rather a potential adverse health outcome that may require additional assessment to either refine the exposure modelling inputs or a more detailed Tier 3 risk assessment.

10.1 Risk characterisation – baseline conditions

The calculated baseline HQs for young child receptor exposures to COPC via the selected exposure pathways in each study area are presented in Table 10.2. The calculated baseline HQs for adult receptor exposures to COPC via the selected exposure pathways in each study area are presented in Table 10.3.

Table 10.2: Hazard Quotient: young child receptors - baseline exposures to COPC associated with individual exposure pathways

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water – second-ary source	Incidental ingestion of water bathing / cleaning / washing purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing activities		Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crust-aceans	Ingestion of local molluscs
Study Area 1 (Tier 1)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.05	<0.01	0.03	0.01	-
	Lead	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.09	0.30	0.02	0.05	<0.01	-
	Mercury	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.35	0.16	***2.37***	0.05	-
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.25	0.51	0.14	0.37	0.07	-
Study Area 1 (Tier 2)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.06	0.02	0.03	0.01	-
	Lead	<0.01	0.19	<0.01	<0.01	<0.01	<0.01	0.14	0.31	0.06	0.05	<0.01	-
	Mercury	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.17	0.37	0.28	***2.37***	0.05	-
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.15	<0.01	0.36	0.37	0.07	-
Study Area 3	Arsenic	-	-	-	<0.01	-	<0.01	<0.01	0.05	<0.01	0.24	0.04	0.02
	Lead	-	-	-	<0.01	-	<0.01	0.05	0.26	<0.01	0.06	0.02	0.05
	Mercury	-	-	-	<0.01	-	<0.01	0.06	0.30	0.05	***2.47***	0.30	0.15
	Zinc	-	-	-	<0.01	-	<0.01	0.05	0.38	0.06	0.02	0.10	0.14
Study Area 4	Arsenic	-	-	-	<0.01	-	<0.01	<0.01	0.05	<0.01	0.26	-	-
	Lead	-	-	-	<0.01	-	<0.01	0.05	0.26	<0.01	0.06	-	-
	Mercury	-	-	-	<0.01	-	<0.01	0.06	0.30	0.05	***2.67***	-	-
	Zinc	-	-	-	<0.01	-	<0.01	0.05	0.38	0.06	0.01	-	-

\- *Indicates exposure pathway was not evaluated for this study area.*

Notes: ***Italicised bolded text*** *indicates HQ >1*

Table 10.3: Hazard Quotient: Adult - Baseline exposures to COPC associated with individual exposure pathways

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water - secondary source	Incidental ingestion of water bathing / cleaning / washing purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crust-aceans	Ingestion of local molluscs
Study Area 1 (Tier 1)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	-
	Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.09	<0.01	0.02	<0.01	-
	Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.10	0.05	0.76	<0.01	-
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.14	0.05	0.12	0.01	-
Study Area 1 (Tier 2)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01	-
	Lead	<0.01	0.08	<0.01	<0.01	<0.01	<0.01	0.03	0.09	0.02	0.02	<0.01	-
	Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.11	0.07	0.76	<0.01	-
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.10	0.12	0.01	-
Study Area 3	Arsenic	-	-	-	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.13	<0.01	<0.01
	Lead	-	-	-	<0.01	-	<0.01	<0.01	0.05	<0.01	0.03	<0.01	<0.01
	Mercury	-	-	-	<0.01	-	<0.01	0.01	0.06	0.02	***1.37***	0.06	0.03
	Zinc	-	-	-	<0.01	-	<0.01	<0.01	0.08	0.02	<0.01	0.02	0.03
Study Area 4	Arsenic	-	-	-	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.14	-	-
	Lead	-	-	-	<0.01	-	<0.01	<0.01	0.05	<0.01	0.03	-	-
	Mercury	-	-	-	<0.01	-	<0.01	0.01	0.06	0.02	***1.47***	-	-
	Zinc	-	-	-	<0.01	-	<0.01	<0.01	0.08	0.02	<0.01	-	-

\- *Indicates exposure pathway was not evaluated for this study area.*

Notes: ***Italicised bolded text*** *indicates HQ >1*

Based on the available data indicative of baseline conditions, the constraints of the exposure modelling and the assumptions used in the health risk evaluation, a HQ of less than 1 was estimated for all COPCs measured in the following media and exposure routes:

- All evaluated exposure pathways associated with the direct and incidental ingestion of water, and dermal contact with water by adults and young children in Study Area 1, Study Area 3 and Study Area 4.
- All evaluated exposure pathways associated with the ingestion of locally sourced terrestrial foods by adults and young children in Study Area 1, Study Area 3 and Study Area 4.
- The ingestion of locally sourced aquatic foods by adults in Study Area 1.

The exposure pathways where the HQ exceeded 1 relate to the ingestion of local fish associated with mercury. Young child receptors in all study areas may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) in locally obtained fresh and/or marine fish under baseline conditions. Adult receptors in coastal study areas may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) in locally obtained marine fish under baseline conditions.

Further refinement of the exposure and media inputs has been noted and will be addressed prior to the Project construction to provide greater confidence in the HHRA outcomes. Further data collection is warranted to refine the assumptions associated with consumption rates estimated from the Ok Tedi Mine regions, the effects of the high LORs of the Market Basket Survey data (Bentley, 2011) on the calculated average concentrations adopted, and the assumption that mercury measured in aquatic biota is in the more toxic organic form of methylmercury.

10.2 Exposures via multiple pathways

To estimate the additive effect of exposure to multiple COPCs via multiple pathways, the HQs can be summed to obtain a Hazard Index (HI). The calculation of a HI may involve the summation of the HQ for multiple COPCs for a particular exposure pathway and receptor in each study area, or the summation of the HQs for a particular COPC across relevant exposure pathways for a receptor in each study area, or both. This assumes additivity in the toxicological outcomes following concurrent exposures.

As a conservative approach, the HQs for an individual COPC across all pathways for each receptor are summed in this HHRA to characterise the potential risks where a scenario involves one or more exposure pathways to calculate the HI.

The additivity of HQs for two or more COPCs is likely to only be relevant when COPCs have a common toxic effect or target organ. As the TDI health endpoints are based on different target organs for each of the selected COPCs the HQ have not been summed. The calculation of HIs associated with each COPC are presented in Table 10.4.

Table 10.4: Equation used to calculate the Hazard Index

Equation 6	$$\boldsymbol{HI_{Contaminant} = HQ_{Exposure\ Pathway\ 1} + HQ_{Exposure\ Pathway 2} + \ldots\ldots + HQ_{Exposure\ Pathway n}}$$
Where: HQ = Hazard Quotient for a COPC and pathway specific exposure (unitless) HI = Summed Hazard Quotient for a contaminant across multiple exposure pathways (unitless)	

Where the HI is less than 1, there is unlikely to be any adverse health effects associated with exposure to the chemicals of concern. However, a HI exceeding 1 does not necessarily indicate an actual risk but rather a potential elevated exposure requiring additional assessment or management. The calculated HI for each COPC for all pathways evaluated for each study area and receptor group are presented in Table 10.5 and provided in greater detail in Appendix F.

Table 10.5: Total Hazard Index calculated for exposure to COPC by receptors in selected study areas

Exposure Pathway	COPC	Total HI - All Exposure Pathways Young Child	Total HI - All Exposure Pathways Adult
Study Area 1 (Tier 1)	Arsenic	0.15	0.03
	Lead	0.62	0.18
	Mercury	***3.80***	***1.21***
	Zinc	***1.68***	0.52
Study Area 1 (Tier 2)	Arsenic	0.18	0.03
	Lead	0.96	0.30
	Mercury	***4.05***	***1.26***
	Zinc	***1.18***	0.33
Study Area 3	Arsenic	0.45	0.18
	Lead	0.55	0.13
	Mercury	***4.17***	***1.96***
	Zinc	0.92	0.20
Study Area 4	Arsenic	0.40	0.20
	Lead	0.47	0.12
	Mercury	***3.85***	***1.99***
	Zinc	0.62	0.14

*Notes: **Italicised bolded text** indicates HI >1*

Based on the available data indicative of baseline conditions, the constraints of the exposure modelling and the assumptions used in the health risk evaluation, a Total HI of less than 1 was estimated for:

- Arsenic and lead exposures to young children in Study Area 1.
- Arsenic, lead and zinc exposures to young children in Study Area 3 and Study Area 4.
- Arsenic, lead, mercury and zinc exposures to adults in Study Area 1.
- Arsenic, lead and zinc exposures to adults in Study Area 3 and Study Area 4.

These conclusions can be further refined based on the contribution of each chemical to the Total Hazard Index associated with exposures to individual pathways to determine the exposure pathways that are driving the health risks.

The COPCs associated with exposure from all pathways evaluated for each study area where the HI exceeded 1 primarily relate to the ingestion of local terrestrial and aquatic biota associated with mercury in fish. Young child receptors in all study areas may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) and zinc in locally obtained terrestrial and aquatic foods under baseline conditions. Adult receptors in coastal study areas may ingest elevated levels of mercury (assumed to be present in the form of methylmercury) in locally obtained terrestrial and aquatic foods under baseline conditions. Mercury ingestion from locally sourced fish was the largest contributor associated with exposures to both young children and adults in all study areas.

The percentage contributions of each exposure pathway to the intake of a COPC in young children is presented in Table 10.6 and in Table 10.7 for adults.

The risk characterisation outcomes in this report are based on the available information and limitations of the exposure modelling are should be considered as relative indicators of baseline conditions in Study Area 1, Study Area 3 and Study Area 4 in conjunction with the uncertainties discussed in Chapter 11.

Table 10.6: Percentage contribution to over Hazard Index - young children

Study Area	**COPC**	**Exposure Pathways Evaluated**											
		Ingestion of drinking water - primary source	**Incidental ingestion of drinking water - secondary source**	**Incidental ingestion of water bathing / cleaning / washing purposes**	**Incidental ingestion of recreation water swimming**	**Dermal contact with water - bathing / cleaning / washing activities**	**Dermal contact with recreation water - swimming**	**Ingestion of local fruit**	**Ingestion of local vegetables /grains**	**Ingestion of local meat and animal products**	**Ingestion of local fish**	**Ingestion of local crustaceans**	**Ingestion of local molluscs**
Study Area 1 (Tier 1)	Arsenic	**3%**	**4%**	<1%	<1%	<1%	<1%	**12%**	**40%**	**5%**	**26%**	**11%**	-
	Lead	<1%	**4%**	<1%	<1%	<1%	<1%	**18%**	**61%**	**5%**	**10%**	**2%**	-
	Mercury	<1%	<1%	<1%	<1%	<1%	<1%	**3%**	**12%**	**5%**	**78%**	**2%**	-
	Zinc	<1%	<1%	<1%	<1%	<1%	<1%	**19%**	**38%**	**11%**	**27%**	**5%**	-
Study Area 1 (Tier 2)	Arsenic	<1%	**2%**	<1%	<1%	<1%	<1%	**17%**	**37%**	**11%**	**23%**	**10%**	-
	Lead	<1%	**25%**	<1%	<1%	<1%	<1%	**19%**	**41%**	**7%**	**6%**	**1%**	-
	Mercury	<1%	<1%	<1%	<1%	<1%	<1%	**5%**	**11%**	**9%**	**73%**	**2%**	-
	Zinc	<1%	<1%	<1%	<1%	<1%	<1%	**15%**	<1%	**38%**	**39%**	**7%**	-
Study Area 3	Arsenic	-	-	-	<1%	-	<1%	**3%**	**12%**	<1%	**66%**	**11%**	**7%**
	Lead	-	-	-	<1%	-	<1%	**12%**	**58%**	**1%**	**12%**	**5%**	**11%**
	Mercury	-	-	-	<1%	-	<1%	**2%**	**9%**	**1%**	**74%**	**9%**	**5%**
	Zinc	-	-	-	<1%	-	<1%	**6%**	**51%**	**8%**	**2%**	**13%**	**19%**
Study Area 4	Arsenic	-	-	-	<1%	-	<1%	**3%**	**14%**	<1%	**82%**	-	-
	Lead	-	-	-	<1%	-	<1%	**14%**	**68%**	**2%**	**16%**	-	-
	Mercury	-	-	-	<1%	-	<1%	**2%**	**10%**	**2%**	**87%**	-	-
	Zinc	-	-	-	<1%	-	<1%	**10%**	**76%**	**12%**	**3%**	-	-

Table 10.7: Percentage contribution to over Hazard Index - Adults

Study Area	COPC	Exposure pathways evaluated											
		Ingestion of drinking water - primary source	Incidental ingestion of drinking water - secondary source	Incidental ingestion of water bathing / cleaning / washing purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crustaceans	Ingestion of local molluscs
Study Area 1 (Tier 1)	Arsenic	4%	6%	<1%	<1%	<1%	<1%	13%	37%	6%	28%	7%	-
	Lead	<1%	5%	<1%	<1%	<1%	<1%	20%	57%	5%	11%	1%	-
	Mercury	<1%	<1%	<1%	<1%	<1%	<1%	4%	10%	5%	79%	<1%	-
	Zinc	<1%	<1%	<1%	<1%	<1%	<1%	21%	35%	11%	29%	3%	-
Study Area 1 (Tier 2)	Arsenic	<1%	3%	<1%	<1%	<1%	<1%	12%	39%	11%	27%	7%	-
	Lead	<1%	34%	<1%	<1%	<1%	<1%	12%	39%	6%	7%	<1%	-
	Mercury	<1%	<1%	<1%	<1%	<1%	<1%	3%	11%	8%	77%	<1%	-
	Zinc	<1%	<1%	<1%	<1%	<1%	<1%	11%	<1%	38%	46%	5%	-
Study Area 3	Arsenic	-	-	-	<1%	-	<1%	<1%	6%	<1%	85%	5%	3%
	Lead	-	-	-	<1%	-	<1%	8%	49%	2%	28%	4%	9%
	Mercury	-	-	-	<1%	-	<1%	<1%	4%	1%	89%	4%	2%
	Zinc	-	-	-	<1%	-	<1%	5%	48%	14%	6%	11%	16%
Study Area 4	Arsenic	-	-	-	<1%	-	<1%	<1%	6%	<1%	92%	-	-
	Lead	-	-	-	<1%	-	<1%	9%	54%	2%	35%	-	-
	Mercury	-	-	-	<1%	-	<1%	<1%	4%	1%	94%	-	-
	Zinc	-	-	-	<1%	-	<1%	7%	67%	20%	6%	-	-

11 Uncertainty and variability analysis

Risk assessments require a number of assumptions regarding site conditions, human behaviours and activities relating to exposure, and chemical toxicity. Even though site-specific parameters were included where available (e.g., dietary and local food information, and analytical data), it is not possible to fully describe current and future conditions and human activities in villages within each study area for the entire period of time considered in the risk assessment (i.e., 70 years for a village setting). The assumptions considered for this risk assessment were generally conservative in nature, to account for uncertainty and variability in the parameter estimates and to protect public health by providing a deliberate margin of safety. The inclusion of upper estimate exposures provided a very conservative estimate of maximum plausible exposures.

Whilst the quantification of risk estimates can be tailored for individuals or groups based on their location, diets and activities, some uncertainty will remain. The aim of this section is to provide a qualitative appraisal of the uncertainties associated with this risk assessment. It is noted that many of the uncertainties relating to data adequacy, data gaps and dietary inputs are intended to be addressed prior to Project construction. Further detail is provided in Chapter 13.

11.1 Uncertainty assessment

An evaluation of the key uncertainties of this risk assessment is presented in Table 11.1.

Table 11.1: Uncertainty assessment

Parameter	Evaluation of uncertainty
Toxicity: Tolerable Reference Values	The toxicity criteria used in this assessment are generally regarded as highly conservative. They are typically derived from exposure levels shown to cause “no adverse effect” following studies of chronic exposure in animals or humans. Safety factors, extending several orders of magnitude may be taken into account for issues related to data extrapolation. Tolerable intake values have been developed by various regulatory agencies such as the US Environmental Protection Agency (USEPA) and the World Health Organization (WHO). These criteria may be different due to different methods of derivation. The selection of toxicological source information is in accordance with international agencies including WHO, USEPA and NEPM.
Exposure Assumptions	A number of conservative exposure assumptions were included in the risk assessment. For example, it was assumed that in the village setting the same individual would be exposed to the same concentration for 365 days/year over a 65 or 70 year lifetime. When combined, the assumptions deliberately overestimate the most likely exposure.
Exposures to Children and Adults	Children were included in the quantitative evaluation on the basis their exposures are potentially greater given their activities (greater hand to mouth contact in young children) and body weight to skin area ratios or ingestion rates. The exposure characteristics of a 2 to 3 year old child were adopted and generally drive the risks in most scenarios.
Data adequacy	A review of the available data and the identification of data adequacy and data gaps was undertaken as part of the Tier 1 (T1) screening assessment (refer to Section 7.3). Whilst a number of the uncertainties are considered in this section other limitations and uncertainties are noted in Section 7.3. Where limitations have been identified in some data sets further investigations will be undertaken.

Parameter	Evaluation of uncertainty
COPC Concentrations	The mean concentrations of each COPC reported or estimated in the baseline investigations and the predicted dissolved water modelling were utilised in this assessment in order to represent a reasonable worst case scenario rather than a worst case. The adoption of mean concentrations of COPCs measured in each waterway or food type are generally considered to be representative of likely intakes, however, concentrations of some contaminants are higher in some locations than others. All food sampling undertaken in the Market Basket survey by Bentley (2011) was conducted at selected villages and was limited to a number of foods sources based on dietary surveys, seasonal availability and accessibility. The adoption of mean concentrations of COPCs measured in each food type are generally considered to be representative of likely intakes, however, concentrations of some contaminants such as arsenic were higher in marine locations than others. The high LORs associated with food analytical data (Bentley, 2011) where the data set is left censored (i.e., a large number of non-detect samples) on the calculated averages is considered to overestimate the COPC concentrations adopted for the Tier 1 (T1) and Tier 2 (T2) evaluations. Any additional investigations where a large number of non-detections are expected should consider a lower LOR. It was conservatively assumed the measured mercury in aquatic foods was 100% methylmercury, the more toxic organic form of mercury often produced in aquatic biota. Speciation of metals including mercury and arsenic would provide a more refined, site specific evaluation. Attention to the LOR and metal speciation will be reviewed in future works.
Food consumption rates	Food consumption rates were estimated based on information relating to the Ok Tedi Mine regions. Whilst assumptions were made as to the comparability of villages in the study areas of interest in this HHRA and villages surveyed in the Ok Tedi Mine regions, there are likely to be differences in the types of food available and the frequency in the consumption of food types and the amount consumed on a weekly or season basis.
Bioavailability	The bioavailability of each COPC varies depending on the exposure route, the chemical form of the metal and many other factors therefore it was conservatively assumed to be 100%. For the assessment of dermal contact, a modification to the tolerable intake was included to represent an internal dose, and this should be compared to the calculated absorbed dermal dose (this precludes direct skin effects associated with a reflection of bioavailability but considers systemic effects associated with an absorbed dose rather than an administered dose). In this assessment, the dermal absorbed doses were calculated through the use of dermal absorption factors applied to oral toxicity values as dermal toxicity reference values were not established.
Proposed management measures iduring construction and operations	A number of assumptions were made regarding the management of potential releases of contaminants to the environment. The health risk assessment evaluation of potential exposures only considered modelling associated with the wastewater discharge pipeline to the Lower Watut River. Other potential releases to environmental media resulting from Project activities are understood to be sufficiently managed during the construction and operational phases, to prevent contaminants reaching water supplies used by villages, impacting soils used for growing edible plants, and other indirect impacts to other local food sources. This includes, but is not limited to: • Waste rock sediment, leachate and related particulate runoff. • Spills/leaks associated with processing and transport of tailings, fuel and other wastes. Surface water management infrastructure associated with the Mine Area is proposed to include pipelines, diversion channels, a retention basin, sediment ponds, dams, spillways and water treatment facilities.

11.2 Parameter sensitivity

A qualitative sensitivity analysis is presented in Table 11.2 to provide information on critical input parameters for the exposure calculations and how this may influence estimates of risk. The confidence in the value is defined as follows:

- Low: Insufficient data set and limited information available from literature sources or no site-specific information available.
- Medium: Small data set or appropriate site/receptor information available from literature.
- High: Reasonable data set or information available specific to the site or receptor population.
- Conservative: Limited site-specific information available therefore a maximum or conservative value was selected. Therefore, although the specific value may not be accurate, the confidence in the scenario being protective is high.

Table 11.2: Parameter sensitivity analysis

<table>
<tr><th colspan="2">Parameter</th><th colspan="2">Exposure model input value</th><th>Confidence in the input value</th><th>Impact of Increase in value on the calculated risk</th></tr>
<tr><td colspan="6">Source Inputs</td></tr>
<tr><td colspan="2">Drinking water concentrations [mg/L]</td><td colspan="2">Various</td><td>High</td><td>Increase</td></tr>
<tr><td colspan="2">Surface water concentrations [mg/L]</td><td colspan="2">Various</td><td>Low</td><td>Increase</td></tr>
<tr><td colspan="2">Predicted surface water concentrations [mg/L]</td><td colspan="2">Various</td><td>Medium</td><td>Increase</td></tr>
<tr><td colspan="2">Terrestrial Biota concentrations [mg/kg]</td><td colspan="2">Various</td><td>Medium</td><td>Increase</td></tr>
<tr><td colspan="2">Aquatic Biota concentrations [mg/kg]</td><td colspan="2">Various</td><td>Medium</td><td>Increase</td></tr>
<tr><td colspan="6">Toxicity Inputs</td></tr>
<tr><td colspan="2">Threshold toxicity reference value [mg/kg/day]</td><td colspan="2">Various</td><td>Conservative</td><td>Decrease</td></tr>
<tr><td colspan="2">Gastro-intestinal absorption factor [%]</td><td colspan="2">100</td><td>Conservative</td><td>Increase</td></tr>
<tr><td colspan="2">Dermal absorption factor [%]</td><td colspan="2">Various</td><td>Medium</td><td>Increase</td></tr>
<tr><td colspan="2">Oral Bioavailability [%]</td><td colspan="2">Various</td><td>Conservative</td><td>Increase</td></tr>
<tr><td colspan="2">Skin Permeability Constant [cm/hr]</td><td colspan="2">Various</td><td>Medium</td><td>Increase</td></tr>
<tr><td colspan="6">Villagers - Exposure Parameters</td></tr>
<tr><td colspan="2"></td><td>Child</td><td>Adult</td><td></td><td></td></tr>
<tr><td colspan="2">Exposure duration [years]</td><td>5</td><td>65</td><td>Conservative</td><td>Increase</td></tr>
<tr><td colspan="2">Body Weight [kg]</td><td>12</td><td>55</td><td>High</td><td>Decrease</td></tr>
<tr><td rowspan="4">Exposure frequency [days/year]</td><td>Washing/bathing/irrigating activities</td><td colspan="2" rowspan="3">365</td><td rowspan="3">Conservative</td><td rowspan="4">Increase</td></tr>
<tr><td>Recreation activities</td></tr>
<tr><td>Primary drinking water source</td></tr>
<tr><td>River drinking water – secondary source</td><td colspan="2">60</td><td>Medium</td></tr>
<tr><td rowspan="2">Exposure time [hours/day]</td><td>Washing/bathing/irrigating activities</td><td>0.13</td><td>0.9</td><td>Medium</td><td>Increase</td></tr>
<tr><td>Recreation activities</td><td>0.5</td><td>1</td><td>Medium</td><td>Increase</td></tr>
<tr><td>Water ingestion rate [L/d]</td><td>Drinking water</td><td>1</td><td>2</td><td>Medium</td><td>Increase</td></tr>
</table>

Parameter		**Exposure model input value**		**Confidence in the input value**	**Impact of Increase in value on the calculated risk**
Water ingestion rate [L/hr]	Washing/bathing activities	0.025	0.0125	Medium	Increase
	Recreation activities	0.05	0.025	Medium	Increase
Exposed skin area [cm^2]	Washing/bathing activities	7545	18,200	High	Increase
	Recreation activities				Increase

Taken as a whole, the assumptions used in the risk assessment are considered to be conservative and tend to adopt the Precautionary Principle (enHealth, 2012) in estimating risk. The risk assessment approach presented does not consider a fully probabilistic estimate of risk (i.e., evaluation of all the permutations of each input value), but presents conditional estimates based on a number of assumptions regarding exposure and toxicity. Thus, it is necessary to specify the assumptions and uncertainties inherent in the risk assessment to place the risk estimates into perspective. Risk assessment methodologies reflect an iterative process of development and as such it should be recognised that this exposure assessment and risk assessment are based on existing methodologies and their limitations which may be subject to change.

12 Potential health effects of the Project

The potential health impacts associated with the proposed Project activities during construction, operation and closure have been discussed as part of the conceptual site model which identified contaminant sources and potential contaminant transport pathways. In first instance, where potential contaminant releases have been identified, appropriate measures will be implemented to manage releases to the environment.

The potential health impacts associated with the modelling of air emissions from the IFO power generation plant are discussed in further detail in this section. The DSTP is evaluated in greater detail to assess the potential health impacts to communities in the coastal study areas who consume food sourced from the Huon Gulf.

12.1 Health impacts - IFO power generation plant air emissions

Air quality modelling undertaken by SLR (2018) predicted emissions during IFO power generating operation may exceed the SO_2 screening criteria at two locations, Ziriruk and Fly Camp. The modelling outcomes indicate Villagers at these locations are potentially exposed to elevated levels of SO_2 for chronic exposure period during the operation phase of the mine. On the basis the identified village receptor populations are potentially exposed 24 hours/day, a Tier 2 (T2) was not deemed warranted. A qualitative evaluation was undertaken based on health effects relating to the most sensitive receptor populations, and assessed based on available health information and climatic conditions in PNG.

To put the predicted exceedances of Project criteria in the context of potential risks to human health:

- The potential human health risks relating to the inhalation of SO_2 in air are generally dependant on the susceptibility of an individual, the activities they undertake and the climatic conditions
- Potential human health risks are likely to be most significant in individuals with asthma, particularly children, who may experience changes in lung function
- The USEPA (2017) concludes that there is a causal relationship between short-term SO_2 exposure and respiratory effects, particularly in individuals with asthma, and changes in lung function generally occur at concentrations an order of magnitude lower than similar changes in non-asthmatic individuals.

Epidemiological and clinical studies demonstrate that temperature and humidity within the range of ambient environmental conditions can affect the health risk (USEPA, 2017). In general, cooler dry conditions have an increased adverse response in comparison with hotter humid conditions (WHO, 2018), such as would be generally experienced at Ziriruk and Fly Camp.

Information relating to the incidence of asthma in Papua New Guinea, reported by the WHO (2018) was “virtually zero” in children. The Global Burden of Disease Study[6] (GBD, 2013) shows the Annual Mortality Rate per 100,000 head of population associated with asthma rises steeply from age 55 and 65 in adult males and females respectively. However, in PNG, risks to human health from asthma need to be considered in the context of the morbidity and mortality due to smoking and vector-borne and infectious diseases, which far exceeds that from asthma.

The asthma exacerbation is dose-related and hence engineering controls to reduce SO_2 emissions will be necessary where the ambient monitoring during mine operations reports one-hour maxima levels exceeding the adopted SO_2 screening criteria. The WGJV is committed to achieving

[6] The Global Burden of Disease Study (GBD) is a comprehensive regional and global research program that assesses mortality and disability from major diseases, injuries, and risk factors. GBD is a collaboration of over 1000 researchers representing over 300 institutions and more than 100 countries. GBD is based out of the Institute for Health Metrics and Evaluation at the University of Washington and funded by the Bill and Melinda Gates Foundation. This data is made available under the Open Data Commons Attribution License: http://opendatacommons.org/licenses/by/1-0/.

compliance with the adopted air quality criteria, and management measures such as scrubbers on the power generation facilities' stacks or increasing the exhaust gas exit velocity will be implemented to achieve compliance. Such investigations can be conducted using actual data when the power plant is in operation but before it is at near peak capacity when it was estimated from modelling that SO_2 conditions will exceed criteria.

12.2 Potential health effects of the Project use of Deep Sea Tailings Placement

12.2.1 Introduction

This section presents in more detail the findings of the assessment of potential health effects of the Project's proposed use of DSTP to manage tailings.

The assessment of potential human health risks of the proposed DSTP involved the following steps:

- Review of studies in relation to the bioaccumulation of metals in the food chain associated with the discharged tailings to Huon Gulf.
- Evaluation of studies undertaken at similar mine projects that included DSTP to assess any scientifically-proven adverse health impacts to the local communities.

12.2.2 DSTP baseline health evaluation

The environmental setting of the proposed Outfall Area has been studied and presented in greater detail in the environmental impact assessments that informed the Project EIS (WGJV, 2018). In the Outfall Area the studies determined that numerous rivers, notably the Markham and Busu rivers near the outfall site, contribute about 50Mtpa of sediment to the Huon Gulf, augmented by ten other rivers along the north shore of the Huon Gulf which contribute another 10Mtpa (Tetra Tech, 2018a). The introduction of some 16.5Mt of tailings by the Project via DSTP per annum will mix with the currently estimated natural background riverine suspended sediment load of approximately 60Mtpa. The receiving area for the sediments has low diversity and low abundance in terms of edible fish species.

The Project tailings will be transported via pipeline from the Mine Area to a mix/de-aeration tank, where it will be mixed with seawater supplied by a seawater intake pipeline at a ratio of one part tailings to four parts seawater. From the mix/de-aeration tank, tailings will be discharged via a DSTP outfall pipeline at a depth of approximately 200m.

In Study Area 4, the Outfall Area will be located 1,600m to the east of Wagang village. Other villages in the Coastal Area, including those in Study Area 3, are known to catch and/or consume seafoods from the Huon Gulf. A deep slope study of pelagic fish within the DSTP area, and a survey of fish sold at local markets in Study Area 4 (Coffey, 2018b) was undertaken to determine the types of fish consumed by locals, where the fish are caught and the baseline concentration ranges of metals in fish tissue.

Metals concentrations in muscle and liver of the bony fish and sharks examined in the deep-slope pelagic characterisation study (Coffey, 2018b) exceeded the adopted health screening criteria for arsenic, copper, mercury, selenium and zinc.

Species observed at the Department of Civil Aviation (locally known as DCA) Point fish market were reportedly captured within the upper 100m of the water column, and in coastal areas south of Lae, typically outside the influence of noticeable sediment plumes from the Markham River. The discussions with local people in Study Area 4 and with fishermen at the Department of Civil Aviation Point fish market indicates local people do not eat the types of fish, particularly sharks, known to inhabit the DSTP study area as most of their catch is obtained in the shallow coastal waters of the Huon Gulf.

As presented in Section 7.1.6, and the deep-slope and market survey, data from the Huon Gulf indicates that the health screening criteria for arsenic and mercury may be exceeded in fish people currently consume in the Huon Gulf, i.e., in the absence of a DSTP discharge. Other metals examined such as copper, nickel, zinc, and manganese occur at low concentrations in fish tissue and infrequently exceed food safety guidelines.

This information suggests that adopted health screening criteria may be already exceeded in fish for arsenic and mercury due to sources such as discharges from major rivers in the region (e.g., Markham River). These rivers contribute large amounts of sediment and associated metals into the Huon Gulf derived from natural geological sources in PNG. Human sources of metals that should also be considered include wastewater discharges, shipping activities and historical artisanal mining.

The Tier 1 (T1) screening assessment of metal contaminants in fish tissue were evaluated in the HHRA, in addition to the quantitative Tier 2 (T2) evaluation which concluded baseline levels of mercury in fish may present an elevated health risk to receptors in the Coastal Area.

12.2.3 DSTP predicted health evaluation

A bioaccumulation and biomagnification study, which included predictive modelling using conservative assumptions, was undertaken to estimate the concentrations of metals that may occur in the fish people eat following the commencement of DSTP discharge.

12.2.3.1 Assessment of metal bioaccumulation from DSTP

A detailed study was undertaken by Tetra Tech (2018a) to evaluate the bioavailability of metals in the Project tailings discharge to the Huon Gulf, and the biological pathways by which metals could be accumulated in fish that people consume. The discussion in this section is based on the Tetra Tech (2018a) study unless otherwise referenced.

The three major pathways by which fish may theoretically accumulate metals from DSTP were identified as:

- Via metal accumulation in benthos that are in direct contact with the tailings deposited on the sea bottom and trophic transfer up the food chain to fish consumed by people.
- Via metals accumulated in micronekton (i.e., shrimp, jellyfish and other small invertebrates that form the base of the food web for fish that people consume) and plankton that are exposed to the tailings plume, and then trophic transfer to fish consumed by people.
- Via direct bioconcentration of bioavailable metals from the DSTP plume into fish across their gills.

The bioaccumulation study evaluated each of these pathways using site-specific information collected from the Huon Gulf and metal bioaccumulation information from other DSTP sites in the region.

The metals of interest evaluated in the bioaccumulation study were arsenic, copper, nickel, manganese, mercury and zinc, selected based on either their predicted concentrations in the Project mine tailings or because they are known potential threats to human health. It is noted that the expected levels of mercury in the mine tailings are orders of magnitude below the other selected metals and was included particularly given exceedance of the screening criteria observed in the baseline data. The findings of the bioaccumulation study are summarised in Sections 12.2.3.2 and 12.2.3.3.

12.2.3.2 Conceptual site model and exposure pathways

Tailings discharged below approximately 200m deep from the proposed DSTP outfall will mix with and entrain seawater such that by the time the solids are deposited on the ocean floor, the tailings will be greatly diluted. It is expected that the bulk of the tailings will descend rapidly along the steep slope shelf with the density current, and be deposited on the sea bottom. Most, if not all, bioavailable metals are expected to be released in subsurface plumes soon after mixing with seawater. The subsurface plumes are not expected to be transported to shallower waters or mix with water closer to the surface because of density differences and the lack of upwelling or currents that would otherwise tend to push plumes upward in the water column. Extensive monitoring information collected for the Huon Gulf and the proposed DSTP site indicates the deep sea bed has very weak interactions with the surface and coastal zones. Oceanographic information from the site demonstrated the deep waters in the Huon Gulf are disconnected from upper, warmer layers of seawater where fish are generally collected for consumption.

A generalised depiction of the potential pathways and interactions that might be relevant for DSTP at the Outfall Area is shown in Figure 12.1.

The benthic flora and fauna were observed to be low in density and diversity in the Huon Gulf (below 1,000m). In contrast, a diverse biological community has been recorded in epipelagic zone (surface to 200m) and mesopelagic zone (200m – 1,000m) of the Huon Gulf, consisting of many species of zooplankton, micronekton, and fish. Biota from each trophic level and the food chain in these water zones are presented in Figure 12.1. Based on information collected for the Project thus far in the Huon Gulf, biota that could occur in the vicinity of the DSTP discharge and subsurface plumes, such as zooplankton, micronekton, and certain species of pelagic fish, could be exposed to metals directly via metals in the subsurface plume, or via the feeding on prey that has similarly been exposed. The bioaccumulation and/or biomagnification of metals via the food chain may form a complete pathway for metals in fish tissues that people consume. Given the fishing habits of local fishermen and the home ranges of deep sea fish, the deep sea benthic species are unlikely to be a source of metals in fish species that people consume.

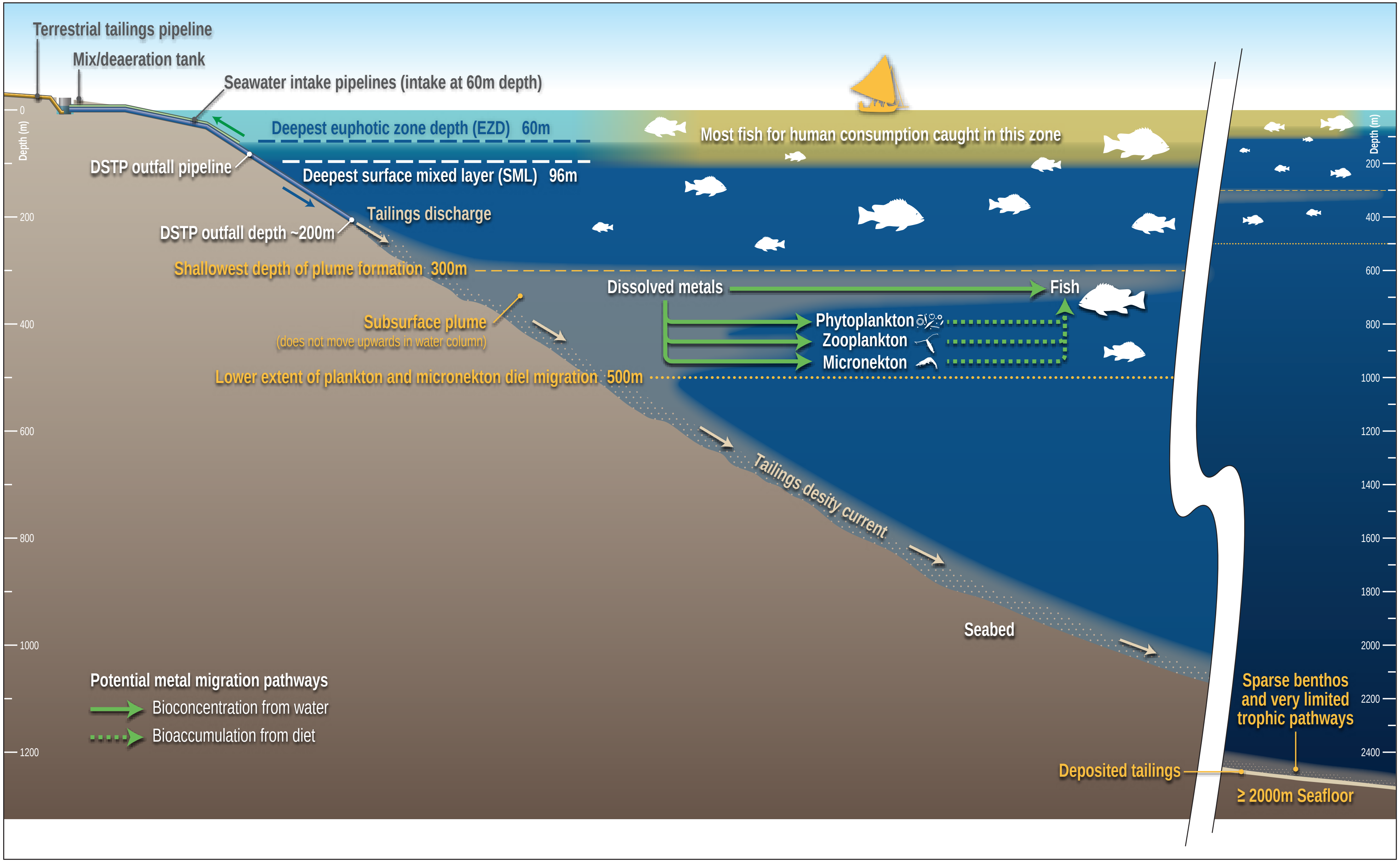
Published journal papers of metal bioaccumulation and biomagnification in biota report mostly low bioaccumulation and limited or no biomagnification of most of the metals of concern in the Huon Gulf (Brewer et al, 2012; Neff, 2002). Tissue concentrations for copper, zinc, nickel, and manganese do not biomagnify in fish that people consume, and bioaccumulation factors follow a similar pattern across all trophic levels for all metals.

Tissue data from different trophic levels within the Huon Gulf indicates that, with the possible exception of mercury, metals evaluated in recent Huon Gulf studies (Coffey, 2018b and 2018e) do not biomagnify in fish that people consume. The available information indicates that for many of the metals examined (copper, zinc, manganese and nickel), tissue concentrations appear highest in zooplankton and micronekton in the Huon Gulf.

12.2.3.3 Predicted metal concentrations in locally consumed fish

The study predicted environmental metal concentrations derived from site-specific three-dimensional modelling and trophic pathway analysis to incorporate both bioconcentration and bioaccumulation of metals in each trophic level (zooplankton, micronekton and fish).

The concentration of each metal of interest in the subsurface plume was estimated from three-dimensional modelling results conservatively assuming that organisms were exposed to the relatively concentrated part of the subsurface plume constantly. The evaluation adopted species-specific ingestion rates and standard bioconcentration and bioaccumulation factors for each metal and it was assumed that each trophic level and fish species was exposed to bioavailable metal in seawater continuously.



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WAFI-GOLPU JOINT VENTURE
Wafi-Golpu Project

Conceptual site model of DSTP and potential exposure pathways of metals to biota

Figure No: 12.1

The screening evaluation predicted tissue concentrations for micronekton and upper trophic levels based on bioconcentration factors (water ingestion) and bioaccumulation factors (prey ingestion) separately. The predicted dissolved metal concentrations in the subsurface DSTP plume and the representative Trophic Level 4 fish species that people consume from the Huon Gulf, based on bioconcentration factors only and bioaccumulation factors only, are presented in Table 12.1. An area use factor was applied to indicate the home range of the fish, in this instance it was conservatively estimated the fish of interest only inhabited subsurface plume waters 10% of the time as they prefer shallow waters. The observed concentration range of metals in fish and the adopted screening criteria (refer to Section 7.1.5) are also shown.

Table 12.1: Predicted metal concentrations in DSTP subsurface plume and fish tissue in the Huon Gulf

Metal	Predicted DSTP Subsurface Plume Concentration (mg/L)(1)	Fish Tissue Metal Concentration (2) (mg/kg)		Maximum Predicted Concentration Considering Area Use Factor (3) (mg/kg)	Existing Concentrations in edible Fish from Huon Gulf (mg/kg)	Screening Criteria – Human Health (mg/kg)
		Water ingestion only	Prey ingestion only			
Arsenic	0.0016	***3.00***	***4.55***	0.455	<0.4 – ***6.2***	2
Copper	0.011	***2.20***	***3.00***	0.3	0.11 – 0.5	2
Manganese	0.011	1.32	2.41	0.241	<0.1 – 0.12	NE
Mercury	0.0000001	***0.53***	***0.53***	0.053	0.03 – ***0.75***	0.5
Nickel	0.0014	0.07	0.087	0.009	<0.06	NE
Zinc	0.012	5.53	7.18	0.72	2.0 – 4.8	15

NE – not established

Values shown in bold and italicised indicate an exceedance of the adopted screening criteria

1. *These concentrations come from the elutriate tests at 1,000 dilutions (as described in Section 2.2 of Tetra Tech, 2018a). A conservative approach was taken whereby, for each metal the highest concentration for two tailings samples, Tailings 1 and Tailings 2, measured at 1;1,000 dilution was adopted as the metal concentration in the subsurface tailings plume. The dilution of 1,000 presented in Tetra Tech (2018a) is within about 1.2km from the outfall and less than 100m radius from where the tailings plume shears off from the density current.*
2. *Wet weight*
3. *Area use factor considers the fish home range. It was assumed most of the fish species consumed by people obtained from the Huon Gulf are likely to spend < 10% of their time at depths exposed to tailings plumes (i.e., below 300m) as their preferred habitat is in shallower depths of <200m. The area use factor of 0.1 was adopted.*

Results of the screening analysis indicate that tissue concentrations of metals are predicted to be low and unlikely to exceed the adopted health screening criteria.

The maximum predicted concentrations (adjusted for area use) of arsenic, mercury, nickel and copper in the edible fish obtained in the Huon Gulf were within the range of concentrations measured in the Market Basket Survey (Bentley, 2011) and the Lae market survey (Coffey, 2018b). The zinc concentrations reported in fish tissue were higher in the Market Basket survey, Lae market survey and deep slope marine survey when compared to the predicted concentrations in fish (adjusted for area use) associated with the DSTP. Manganese levels were predicted to increase; however, manganese is an essential dietary element required for bone mineralisation and metabolic regulation and screening criteria has not yet been established.

The predicted mercury concentrations in fish were higher than the range of concentrations measured in the Market Basket and Lae market surveys. The predicted mercury concentrations did not change with the adjusted area use modelling as the source of the mercury is from background water quality, rather than the mine tailings.

12.2.3.4 Conclusions of the predicted bioaccumulation and biomagnification concentration study

A review of potential exposure pathways found that the transfer of metals from benthic sediments and/or benthic organisms into fish consumed by people is an incomplete trophic pathway.

The metal bioaccumulation and biomagnification study found that locally consumed fish caught in the Huon Gulf may accumulate metals via water and food ingestion from the subsurface plumes formed as a result of DSTP. The bioaccumulation study predicted that concentrations of all metals evaluated will not biomagnify to concentrations measurably above background ranges in fish humans consume.

The analysis of trophic pathway modelling assumed the zooplankton, micronekton, fish that consume micronekton, and top trophic level fish are continuously exposed to subsurface plumes. This is a highly conservative assumption and is known not to reflect the behaviour of these fauna. With the exception of copper, none of the metals examined were predicted to increase measurably above background ranges as a result of DSTP. Whilst arsenic and mercury are predicted to exceed the screening criteria, they are within the background ranges currently detected in fish in the Huon Gulf and therefore are not due to DSTP discharge.

The outcomes of the modelling indicate that DSTP is not predicted to result in metals concentrations exceeding the adopted screening criteria when also considering appropriate species home ranges. Fish species consumed by humans were considered to spend less than 10% of their time in the DSTP area, and even less time within the subsurface plumes.

The predicted bioaccumulation results derived from these analyses are supported by other studies of metal bioaccumulation in fish in PNG and other tropical Asia-Pacific locations, and from metal bioaccumulation information from the published literature. Consistent with the findings of this assessment, these studies have found no bioaccumulation and biomagnification of metals concentrations beyond background in fish people consume due to DSTP.

12.2.4 Recent reviews of DSTP projects

Mine wastes have been discharged to the sea at varying depths worldwide for many years but the concept of ‘deep sea’ placement originated in the late 1980s. The DSTP method is used around the world and examples include the Lihir, Simberi, Ramu and Misima gold mines in PNG and the Batu Hijau mine in Indonesia.

Potential direct human health impacts arising from DSTP may be via the intake of contaminant metals/metalloids through consumption of contaminated fish. This potential impact has been investigated at other DSTP – and shallow water marine discharge – projects and the results of publicly-available, scientific literature relating to this are summarised below for context.

In a study of the Lihir fisheries in 1999-2002, Brewer et al. (2007) analysed trace metal concentrations in fish tissues from 975 fish of 98 species, mainly deep-water fish (20 – 350m). Trace metal concentrations (arsenic, cadmium, copper, cobalt, mercury, lead, nickel, zinc, aluminium, silver and selenium) in fish tissues were compared with individuals caught at different distances from the mine or in different plume regions. Almost all fish analysed showed no difference in trace metal concentrations between areas, and most fish showed no correlation between metal concentrations and distance from the mine for all or most of the trace metals examined.

The concentrations of most trace metals were also similar before and after the commencement of mining suggesting the metals found in fish tissues are probably not due to the effect of the mine but reflect the naturally occurring concentrations of these trace metals around the Lihir Islands group.

Bentley and Soebandrio (2017) studied the effects of shallow-water tailings disposal from the Mesel gold mine in the Ratatotok Subdistrict (North Sulawesi, Indonesia) of Indonesia on contaminant metal intake by local fish-eating communities. Local communities were concerned that health effects were arising from consumption of seafood contaminated with increased levels of arsenic and mercury. The Mesel mine operated between 1996 and 2004 with tailings disposal via an engineered submarine tailings placement into shallow water in Buyat Bay at a depth of 82 m. This project did not meet the critical success factors for DSTP (SAMS, 2010) and, therefore, represents what can happen when tailing is discharged directly into the productive, shallow-water marine ecosystem. Approximately 4.5 million m^3 of detoxified tailings were discharged from 1996 to 2004 through a submarine tailings pipeline at a depth of 82m, some 800m from the shoreline of Buyat Bay. Mercury and arsenic levels measured in the pre-mining baseline assessment, in addition to monitoring conducted during Mesel operations and post-closure, confirmed that exceedances were unrelated to the tailings deposited into Buyat Bay (Bentley and Soebandrio, 2017).

12.2.5 Potential health risks associated with the DSTP

The potential health risks associated with the proposed DSTP were evaluated based on the following lines of evidence:

- Quantitative evaluation of the potential bioaccumulation and biomagnification of metals in the fish locals in Study Area 3 and Study Area 4 consume that are caught in Huon Gulf.
- A review of other DSTP projects to determine the long-term outcomes of similar projects to human health.
- Comparison with the quantitative Tier 2 (T2) baseline health risk evaluation of baseline conditions for villagers in Study Area 3 and Study Area 4.

The outcome of the bioaccumulation study found the predicted levels of metals in the fish people eat do not exceed the adopted screening criteria (with the exception of mercury), and are within the concentration ranges measured in baseline studies. The study concluded the DSTP was not predicted to measurably increase the levels metals currently detected in fish tissue. The outcomes were consistent with studies of mines that have used or are currently using DSTP for tailings management. The Tier 2 (T2) baseline health risk assessment determined that the only metal in fish consumed by villagers in Study Area 3 likely to exceed the tolerable daily intake was mercury. It is noted mercury is not considered to be a metal of concern in the DSTP tailings as the predicted concentrations are negligible (<0.000001 mg/L). On this basis, the outcomes of both the Tier 2 (T2) baseline assessment and the predicted bioaccumulation study indicate that whilst mercury levels are currently elevated and exceed the adopted screening criteria, mercury levels in the fish people consume from Huon Gulf are not expected to increase as a result of the proposed DSTP.

Based on the information used in the HHRA baseline and bioaccumulation studies for the Huon Gulf, other metal concentrations predicted in fish tissue are generally below the screening criteria or where estimated to be within the tolerable daily intakes. This conclusion is further supported based on published information related to species metal uptake and bioaccumulation potential for the metals of concern, and the review of DSTP sites in the Asia-Pacific region.

13 Conclusions

Baseline and modelled proposed Project conditions have been quantitatively evaluated for human health via a Tier 1 (T1) screening assessment and a more detailed Tier 2 (T2) assessment to assess young children and adults in the selected study areas of concern. The study areas of interest were selected based on proximity to mining activities and downstream locations where receptors may be affected during construction and operations for the Lower Watut River and Huon Gulf. Contaminant sources and potential migration to nearby and downstream receptors were reviewed, in conjunction with social and dietary surveys of identified villages to determine potentially complete pathways.

Study Area 1 comprised villages located close to the Mine Area, generally in the highlands (Tier 1 villages), and also located in the lowlands and Lower Watut River floodplains (Tier 2 villages) at a greater distance from the Mine Area, downstream of potentially impacted waterways (including creeks, streams, rivers and groundwater). Study Area 1 villages were considered to potentially be exposed to metals leaching, or in suspended particulate form, from soils disturbed during construction activities, waste storage or waste discharge. Whilst management measures are proposed to collect contaminants in runoff, leachate and other waters, and in soils, wastewater will be discharged to the Lower Watut River during Project operations.

Study Area 2 is located along the proposed infrastructure corridor where impacts are likely to be limited in time and nature. Management measures are proposed to minimise and prevent the release of contaminants in soils, runoff and waterways therefore Study Area 2 was not evaluated further in this HHRA.

Coastal Study Area 3 and Study Area 4 are located along the shores of Huon Gulf and may potentially be impacted as a result of operations at the proposed Port Facilities Area, the Outfall System located on the northern shore east of Lae, and indirectly via DSTP.

The conclusions of the Tier 1 (T1) and Tier 2 (T2) human health assessments are summarised below.

13.1 Human health – baseline conditions

13.1.1 Tier 1 (T1) screening assessment

The Tier 1 (T1) screening assessment determined no exceedances of the adopted human health screening criteria for drinking water, recreational waters (fresh and marine), sediments and terrestrial foods. Metals in aquatic biota exceeded the adopted screening criteria for the following:

- Study Area 1: Average concentrations of zinc reported in freshwater fish.
- Study Areas 3 and 4: Average concentrations of mercury reported in deep sea marine fish consumed by receptors in the coastal study areas.

The analysis of biological specimens indicated villagers in Study Area 1 and Study Area 3 are currently exposed to elevated levels of some COPCs. The concentrations of mercury, lead and arsenic in biological specimens collected from villagers in Study Area 3 reported exceedances of the adopted criteria. Arsenic levels measured in urine specimens were observed in Study Area 1 at concentrations exceeding criteria however it was noted a significantly larger percentage of participants exceeded screening criteria from Study Area 3 villages.

13.1.2 Tier 2 (T2) Quantitative human health assessment – baseline

The selection of contaminants of concern in the Tier 2 (T2) assessment are determined by the Tier 1 (T1) evaluation of measured concentrations in baseline media, known chronic human toxicity and their presence in biological specimens at elevated levels. The potential intakes of arsenic, lead, mercury and zinc by receptors in Study Area 1, Study Area 3 and Study Area 4 were estimated for the following exposure pathways:

- Incidental ingestion of COPCs in water whilst undertaking bathing, washing, irrigating or recreational activities such as swimming or fishing.
- Dermal contact with COPCs in water whilst undertaking bathing, washing, irrigating or recreational activities such as swimming or fishing.
- Ingestion of COPCs in drinking water from primary and secondary water sources.
- Ingestion of COPCs in freshwater or marine fish, crustaceans or molluscs, and terrestrial foods including locally sourced fruits, vegetables, nuts, grains, meat and animal products (such as eggs of milk).

The outcomes of the Tier 2 (T2) baseline assessment are presented in Figure 13.1 and Figure 13.2.

Based on the available data, the exposure modelling and parameters adopted, potential exposures to a COPC is via multiple exposure pathways to the following:

- Young child receptors in all study areas may be exposed to elevated levels of mercury under baseline conditions.
- Young child receptors in Study Area 1 may be exposed to elevated levels of zinc under baseline conditions.
- Adult receptors in coastal study areas may be exposed to elevated levels of mercury under baseline conditions.

Further refinement of the exposure and media inputs would be required to provide greater confidence in this result given the uncertainties associated with consumption rates estimated other regions in PNG, the effects of the high LORs of the Market Basket Survey data (Bentley, 2011) on the calculated average concentrations adopted, and the assumption that measured mercury in aquatic biota is in the more toxic organic form of methylmercury.

The analysis of biological specimens indicates villages in Study Area 1 and Study Area 3 are currently exposed to elevated levels of some COPCs. The levels of mercury, lead and arsenic in biological specimens collected from villagers in Study Area 3 reported exceedances of the adopted criteria. Arsenic levels measured in urine specimens were noted in Study Area 1 at concentrations exceeding criteria however it was noted a significantly larger percentage of participants exceeded screening criteria from Study Area 3 villages.

Many of the data gaps identified in the report (refer to Chapters 7 and 8) are intended to be addressed prior to Project construction. Further data collection relating to soil, terrestrial and aquatic foods, primary and secondary drinking water sources, air quality and dietary information will be obtained to refine the outcomes of the baseline assessment of the HHRA.

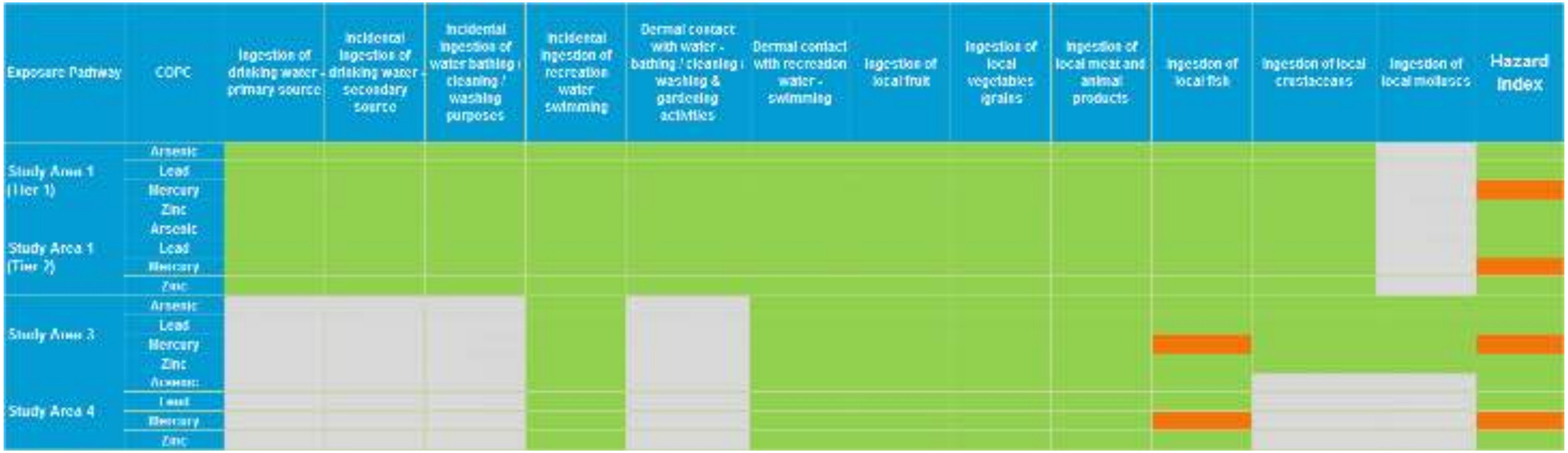
Figure 13.1: Estimated Hazard Quotient outcomes – young children

Green shaded cells indicate the potential exposures for the exposure scenario have been identified as low and tolerable.

Grey shaded cells indicate data was not available for these study areas.

Orange shaded cells indicate an exposure exceeding the tolerable daily intake has been identified and further refinement of risk inputs or management may be required for this pathway.

Figure 13.2: Estimated Hazard Quotient outcomes – adults



Green shaded cells indicate the potential exposures for the exposure scenario have been identified as low and tolerable.

Grey shaded cells indicate data was not available for these study areas.

Orange shaded cells indicate an exposure exceeding the tolerable daily intake has been identified and further refinement of risk inputs or management may be required for this pathway.

13.2 Human health – modelled predicted Project conditions

13.2.1 Impacts of the wastewater pipeline discharge on Study Area1

The predicted surface water concentrations of dissolved metal contaminants relating to Project wastewater discharges in Study Area 1 were based on modelled results undertaken by BMT WBM (2018).

The maximum concentrations of predicted dissolved metal concentrations at assessment points down stream were below the adopted Tier 1 (T1) screening criteria indicating the health risks associated with the proposed wastewater discharge pipeline to the Lower Watut River were considered to be low.

13.2.2 Impacts of air emissions from the IFO power plant

Based on the available health information relating to the inhalation of SO_2 in ambient air, healthy children and adults are not expected to be affected by the SO_2 concentrations predicted at Ziriruk and Fly Camp. The elevated SO_2 air emissions from the IFO generators were predicted during certain plant conditions during the operational phase of the Project.

A qualitative evaluation of potential health effects was identified in asthmatic individuals at these locations. The WGJV is committed to achieving compliance with the adopted air quality criteria, and management measures such as scrubbers on the power generation facilities' stacks or increasing the exhaust gas exit velocity will be implemented to achieve compliance. Such investigations can be conducted using actual data when the power plant is in operation but before it is at near peak capacity when it was estimated from modelling that SO_2 conditions will exceed criteria.

13.2.3 Impacts of the DSTP on Coastal Study Areas 3 and 4

The potential health risks associated with the proposed DSTP has been evaluated based on the baseline Tier 2 (T2) evaluation that found mercury levels in fish consumed by villages in Study Area 3 and Study Area 4 exceeded the tolerable daily intakes, and the predicted levels of mercury in these fish were not expected to change based on the bioaccumulation study. The concentration of manganese is predicted to double the observed background range as a result of DSTP, however the predicted concentration is relatively low compared to amounts of manganese required in the human diet. The results of trophic pathway modelling indicate that there is limited biomagnification of most metals in fish consumed from Huon Gulf.

The predicted bioaccumulation results are supported by other studies of metal bioaccumulation in fish in PNG and other tropical Asia-Pacific locations, in addition to metal bioaccumulation information from the published literature. Consistent with the findings of this assessment, these studies have found no bioaccumulation and biomagnification of metals concentrations beyond background due to DSTP.

13.2.4 Mine closure

The generation of poor quality groundwater (particularly associated with low pH) within the block caves represents a potential source of long-term impact to groundwater discharge features, particularly the groundwater springs, and contribution to base flows of Nambonga Creek, Buvu Creek and Wafi River. The springs are also known to represent a preferred potable water supply in the wider Project area. Potential issues relating to discharge from the subsidence zone lake were also noted to present a hazard to down-gradient soils and water sources. The potential direct and indirect impacts to human health is likely to be significant where groundwater of this quality discharges to the environment following closure.

A number of management and mitigation measures are proposed to manage potential exposures relating to impacted groundwater discharge to identified springs or waterways, in addition to managing the subsidence zone lake groundwater and surface water discharges. It is noted the estimated volume of impacted water associated with the block caves and subsidence zone lake is considered significant and the impact is likely to persist for over 50 years following mine closure. Ongoing monitoring of groundwater flow will provide the information to determine potential exposure to future receptors and their food sources. The information will determine the measures required to manage future risks before mine closure.

13.3 Limitations

The conclusions of the HHRA are based on the available data the current Project description, the limitations of the exposure modelling and the implementation of the Wafi-Golpu Environmental Management Plans.

The risk assessment has been limited to addressing the impacts of selected substances, to a specific assumed receptor population under a defined exposure scenario, based on information available at the time of the assessment. The risk assessment approach presented does not consider a fully probabilistic estimate of risk, but presents conditional estimates based on a number of assumptions regarding exposure and toxicity consistent with the internationally endorsed regulatory approaches. Further assessments would be required to assess risk where site uses vary from the assumed site conditions and/or exposure settings used in this risk assessment.

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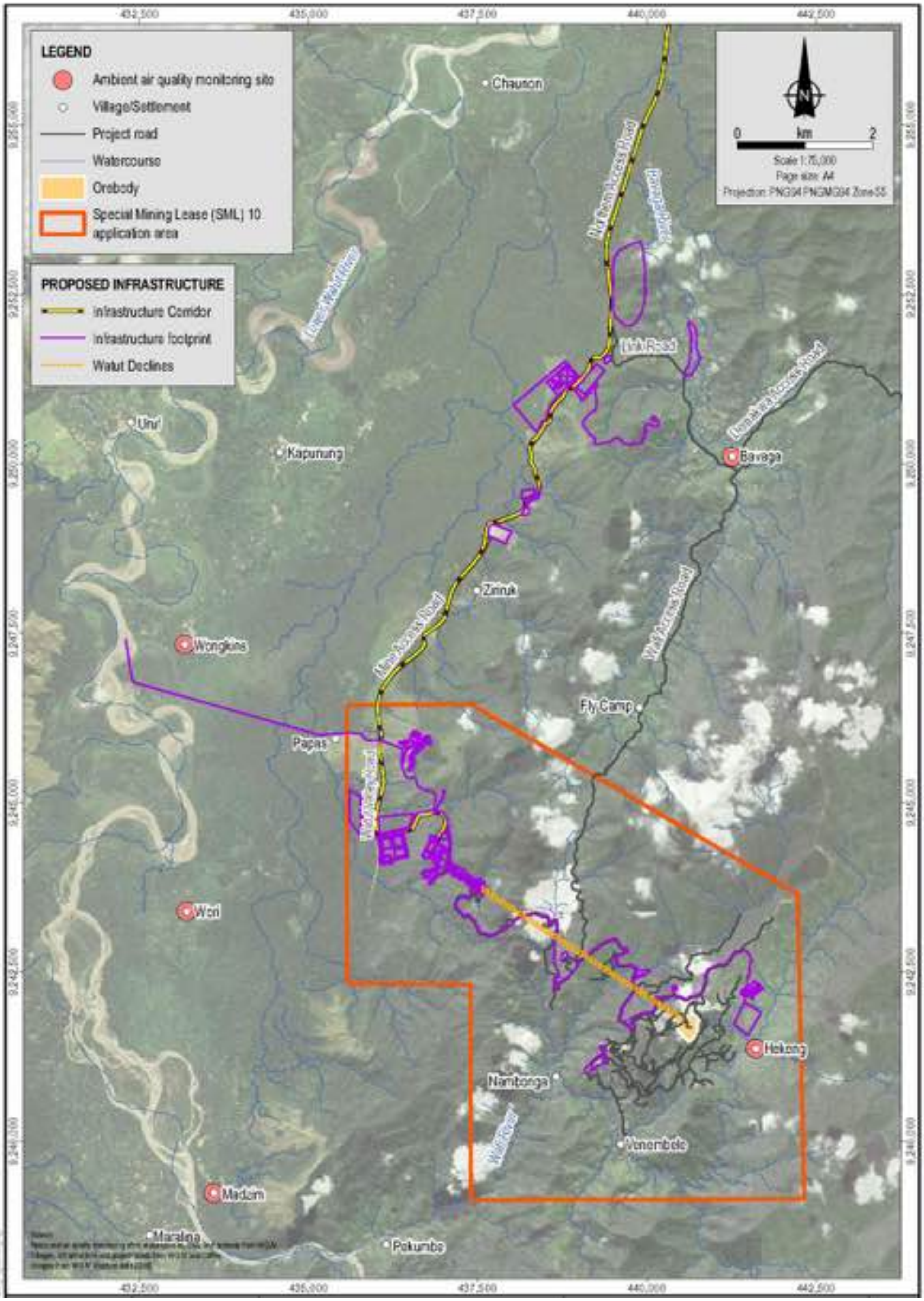
Appendix A - Figures

A TETRA TECH COMPANY

Sampling Location Figure A.1:

Relating to Table A in Appendix B

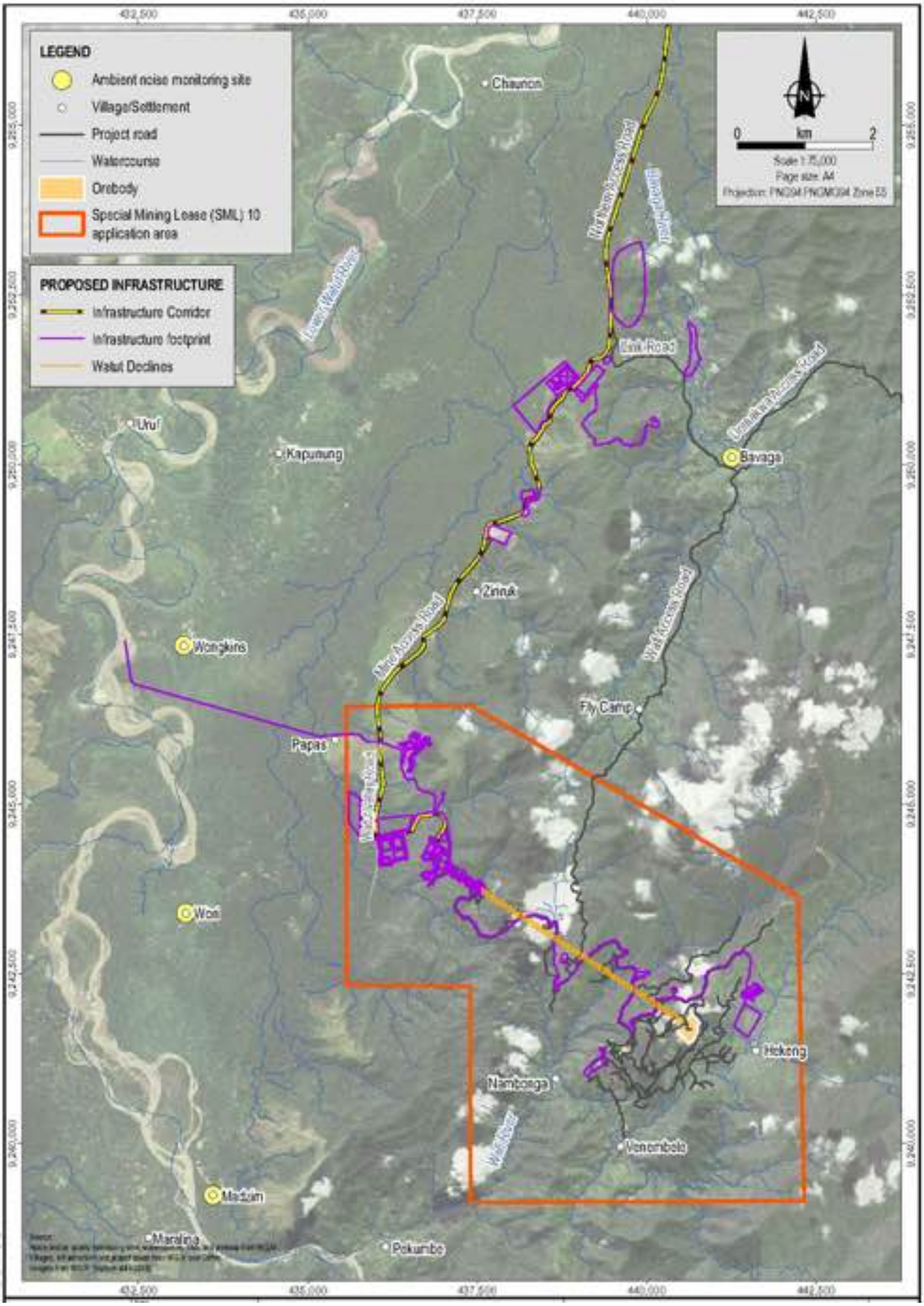
Location of Baseline Air Quality Monitoring Sites



Sampling Location Figure A.2:

Relating to Table A in Appendix B

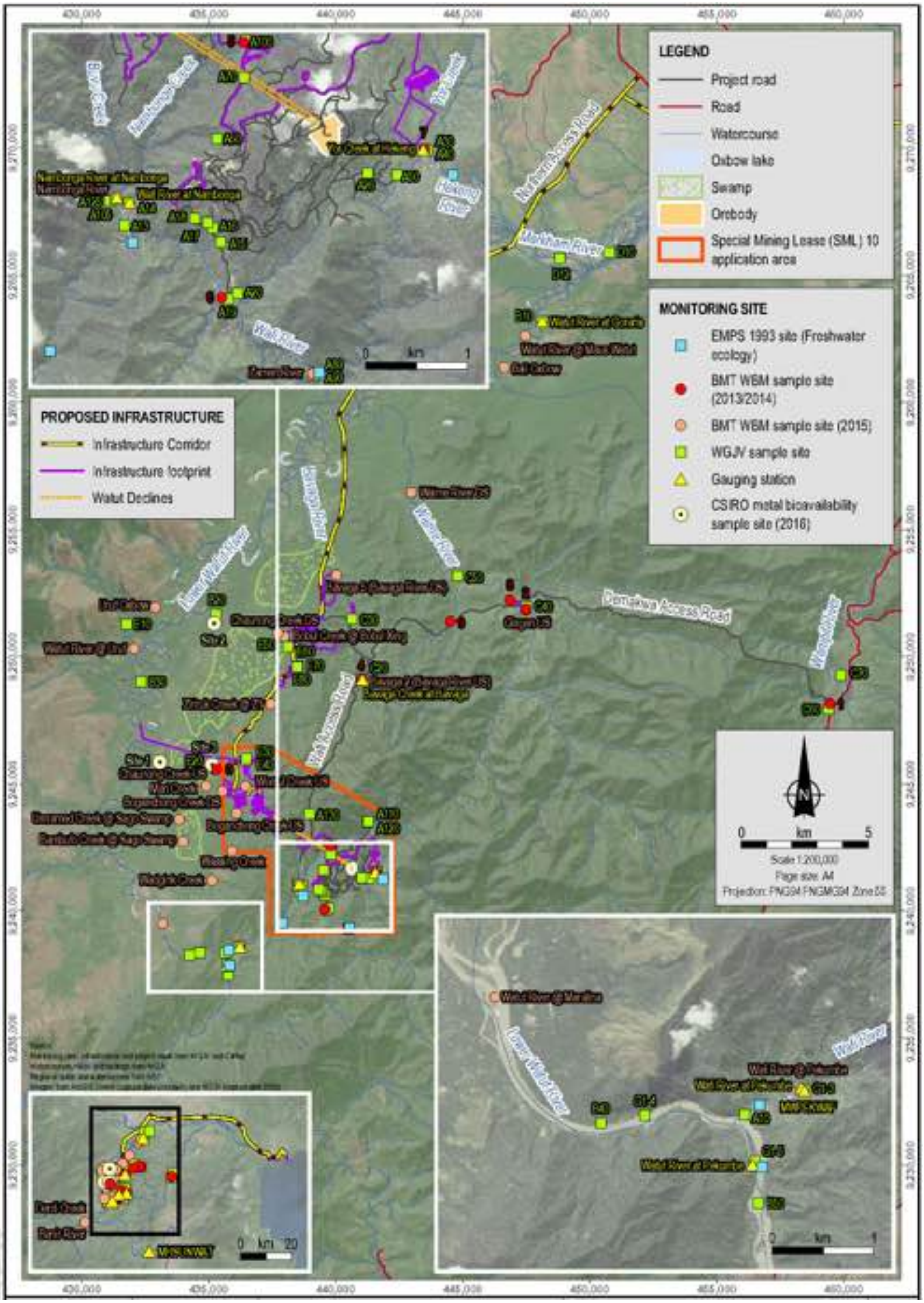
Location of Baseline Noise Monitoring Sites



Sampling Location Figure B:

Relating to Table B and Table G in Appendix B

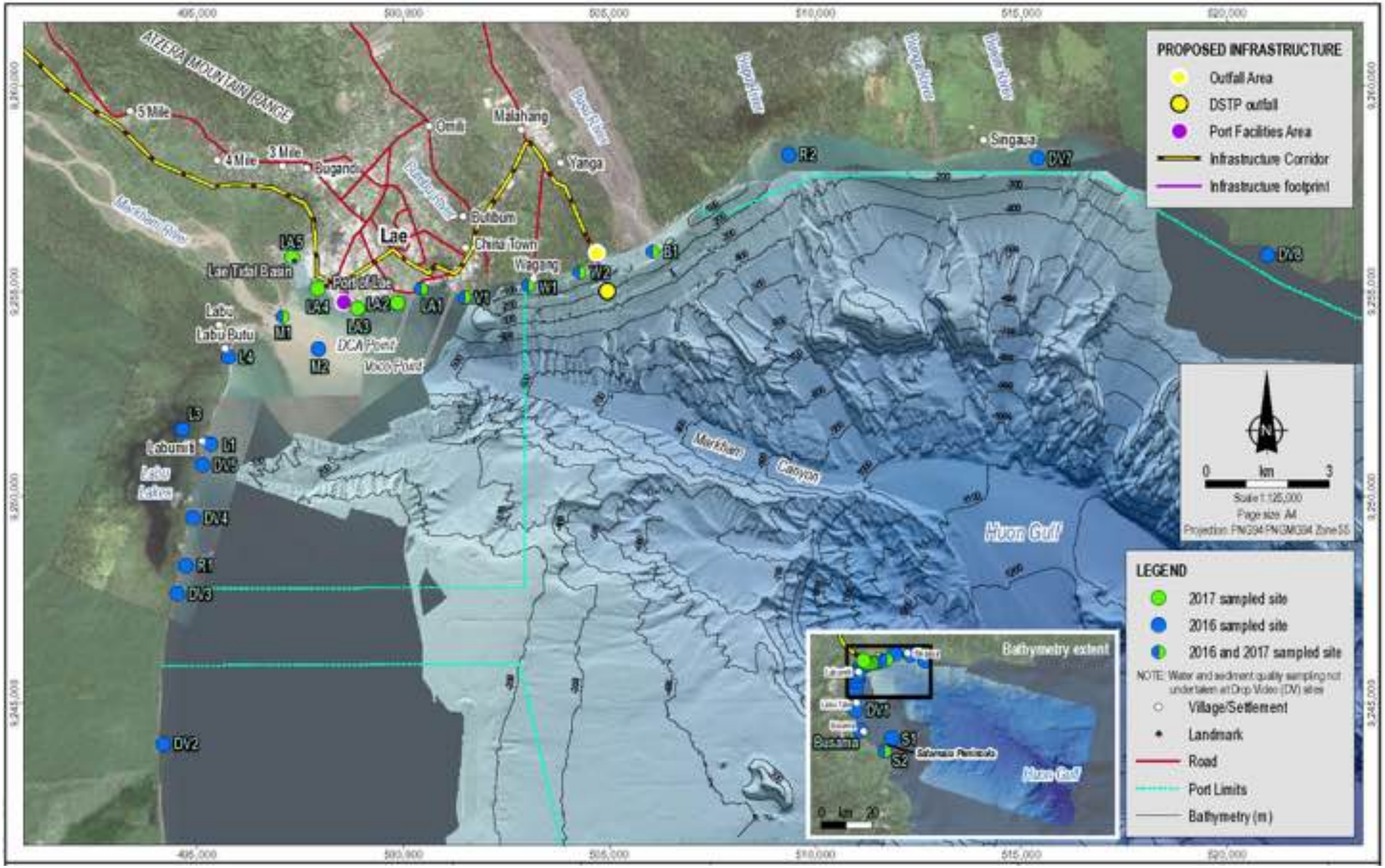
Monitoring Sites and Stream Gauging Stations in the Lower Watut River Catchment



Sampling Location Figure C:

Relating to Table H in Appendix B

2016 – 2017 Nearshore Marine Survey Sampling Sites



Wafi-Golpu Project
Human Health Risk Assessment - Appendix A

Appendix B - Tables

Table A
Ambient Air Data - Baseline

Dust Deposition Monitoring Data				
Month Ending	Total Insoluble Matter Deposition Rate (g/m^2/month)			
	Wongkins Village	Wori Village	Madzim Village	Bavaga Village
	DDG01/Receptor 17	DDG02/Receptor 16	DDG03/Receptor 25	DDG04/Receptor 8
6-Jun-11	0.7	**9.4**	1.4	1.5
3-Jul-11	1.6	1.4	1.3	1.1
31-Jul-11	2.4	3	**6.1**	1.4
28-Aug-11	1.2	1.5	1.6	2
2-Oct-11	1.4	2.3	1.5	-
3-Nov-11	1.5	-	-	1.3
30-Jan-12	2.7	2.4	1	2.1
1-Apr-12	2.3	**7**	-	1.7
30-Apr-12	-	2.3	-	1.7
24-Jun-12	3.6	1.6	2.7	2
27-Jan-13	1.5	1.4	1.6	1.2
19-Mar-13	1.5	1.4	1.3	2.2
1-Apr-13	1.6	3.5	1	1.7
5-May-13	1.7	1.5	0.3	1.3
26-May-13	2.2	1.1	3.3	1.4
29-Sep-13	1.1	0.9	1.6	1.6
28-Oct-13	1.8	1.1	1.7	1.1
24-Nov-13	0.5	3.9	1.4	1.8
18-Dec-13	2.4	2.9	2.1	3.2
29-Jan-14	1.3	**4.1**	-	1.2
25-Feb-14	2.3	1.7	-	3.4
31-Mar-14	2	3.1	-	2.2
29-Apr-14	2.5	**5.2**	-	1.9
25-May-14	0.7	0.8	-	0.8
29-Jun-14	0.9	1	-	0.9
20-Jul-14	1.2	1.1	-	1.1
18-Aug-14	0.9	2.6	-	3.5
5-Oct-14	1.5	0.9	-	0.5
22-Oct-14	2.3	**5.1**	-	1.2
23-Nov-14	2.2	1.8	-	1.6
11-Dec-14	1.4	1.6	-	2.1
25-Jan-15	1.3	1.5	-	0.4
7-Feb-15	0.8	0.7	-	0.9
29-Mar-15	1.2	0.6	-	0.6
29-Apr-15	1.6	1.6	-	1
31-May-15	1.6	2.3	-	1.5
Average	**1.6**	**2.4**	**1.9**	**1.6**

Notes:

1 Bold figures are above the annual average criterion of 4 g/m2/month for cumulative impacts widely used in Australia to protect against nuisance dust impacts.

2 The Madzim Village DDG was relocated in January 2014 to enable background data collection in the vicinity of the (then) proposed Exploration Shaft at the Golpu Drillers Facility to commence.

PM_{10} Monitoring Data		
	24-Hour Average Concentration (µg/m^3)	Averaging Period
Wongkins	33	24 hour period ending 11:00 AM 12 May 2011
Wori	4	24 hour period ending 2:50 PM 12 May 2011
Bavaga	26	24 hour period ending 12:00 PM 14 May 2011
Madzim	5	24 hour period ending 4:00 PM 14 May 2011

Source: SLR. 2016. Golpu Project: Air Quality and Greenhouse Gas Assessment. Report prepared for the Wafi-Golpu Joint Venture.

Table B
Sediment Data - Baseline

BMT WBM total metals/metalloids in sediment (mg/kg) data

Aquatic ecosystem type	Sub-catchment	Site	Date	Ag	As	Cd	Cr	Co	Cu	Hg	Mn	Ni	Se	Sb	V	Zn
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
High to moderate gradient tributary stream	Bavaga	Bavaga US	Mar-15	<0.1	2.31	<0.1	86.9	15.1	23.5	0.03	474	57.9	1.2	<0.50	87.2	50.6
	Bavaga	Bavaga DS	Mar-15	<0.1	1.93	<0.1	105	17.5	26.4	0.04	547	70.4	1.2	<0.50	92.3	47
	Wafi	Nambonga	Mar-15	0.5	147	1	207	34.5	87.6	0.39	845	130	8.1	1.75	121	229
	Wafi	Zamen	Mar-15	<0.1	4.41	<0.1	81.3	13.8	38.1	0.08	639	58	1.2	<0.50	61.4	71
	Wafi	Wafi @ Pekumbe	Mar-15	<0.1	13.8	0.1	77.7	14.7	31.4	0.12	558	56	1.5	<0.50	57.8	65.8
	Waime	Waime US @ Gingen	Mar-15	<0.1	4.97	<0.1	38.7	10.7	26.5	0.04	646	27.7	0.9	<0.50	45.9	60.9
	Waime	Waime DS	Mar-15	<0.1	4.06	<0.1	45.4	13	25	0.03	594	32.9	1	<0.50	44.2	63.7
	Banir	Banir	Mar-15	<0.1	3.69	<0.1	58.7	20.1	67.9	0.04	843	70.3	2.1	<0.50	122	67.5
	Banir	Denti	Mar-15	<0.1	2.85	<0.1	84.3	15.8	25.5	0.02	484	48.4	1.4	<0.50	85.7	50.6
	Lower Watut floodplain	Womul @ W1	Mar-15	<0.1	2.85	<0.1	78.4	16.8	29.1	<0.01	590	47	2	<0.50	98.2	61.3
	Lower Watut floodplain	Ziriruk @ Z1	Mar-15	<0.1	1.76	<0.1	28.6	14	24.5	<0.01	664	18.9	2.1	<0.50	143	65.9
Low gradient floodplain streams and wetlands	Lower Watut floodplain	Bobul Xing	Mar-15	0.4	38.6	0.3	66.1	27.6	79.3	0.16	2020	56.3	3.5	<0.50	110	131
	Lower Watut floodplain	Womul DS/ Chaunong US	Mar-15	<0.1	4.62	<0.1	99.1	29	35.3	0.03	1300	66	2.2	<0.50	96.4	74.4
Oxbow	Lower Watut floodplain	Bali Oxbow	Mar-15	<0.1	9.69	<0.1	48.1	17.2	46.7	0.05	713	39.2	1.9	<0.50	86.9	84.5
	Lower Watut floodplain	Uruf Oxbow	Mar-15	<0.1	3.63	<0.1	17	20.4	59.4	0.04	848	13	1.9	<0.50	150	66.3
Unconfined, Turbid Major River Systems	Lower Watut	Watut @ Uruf	Mar-15	0.2	20.4	0.1	32.9	12.6	35.9	0.04	660	29.2	1.2	<0.50	61.4	71.7
	Lower Watut	Watut @ Maralina	Mar-15	0.3	21.1	0.1	22.8	8.9	27.8	0.02	524	19.9	0.9	<0.50	49	63.7
	Lower Watut	Watut @ Maus Watut	Mar-15	0.1	12.9	<0.1	32.7	11.2	24.1	0.03	580	26.4	1.2	<0.50	73.1	54.3
High to moderate gradient tributary stream	Lower Watut floodplain	Boganchong US	Jun-15	<0.1	1.78	<0.1	69.2	14.4	20.9	-	507	44.2	0.2	<0.50	51.9	45.3
	Lower Watut floodplain	Wassing	Jun-15	<0.1	2.42	0.1	108	14.9	27.7	-	543	54.7	0.3	<0.50	61.8	46.4
	Lower Watut floodplain	Wadgink	Jun-15	<0.1	2.18	<0.1	96.7	24.2	32.6	-	955	56.2	0.3	<0.50	69.3	52.6
	Lower Watut floodplain	Chaunong DS	Jun-15	0.3	15	0.2	39.7	14.1	44.8	-	672	32.6	0.5	<0.50	63.3	78.1
	Lower Watut floodplain	Mari	Jun-15	0.2	9.51	0.2	57.4	20	64.2	-	3980	45.5	0.6	<0.50	61	86.2
	Lower Watut floodplain	Swamp@ Bambufo	Jun-15	0.2	13.2	0.1	46.2	18	58.6	-	1420	35	0.6	<0.50	88.8	78.5
	Lower Watut floodplain	Swamp@ Unknown	Jun-15	0.3	14.9	0.2	54.8	22	69.1	-	3840	47.3	0.7	<0.50	75.6	108
Low gradient floodplain streams and wetlands	Lower Watut floodplain	Boganchong DS	Jun-15	<0.1	1.69	<0.1	53.3	11.7	21.3	-	912	31	0.2	<0.50	51	34.5
High to moderate gradient tributary stream	Bavaga	Bavaga 1	Dec-16	<0.1	1.98	<0.1	94.4	12.4	24	-	408	62.7	0.1	<0.50	78.8	41.6
	Bavaga	Bavaga 2	Dec-16	<0.1	2.6	<0.1	108	20.2	32.7	-	681	73.6	0.1	<0.50	105	59.2
	Bavaga	Bavaga 3	Dec-16	<0.1	1.98	<0.1	152	23.1	30.9	-	581	93.1	0.1	<0.50	107	48.2
	Bavaga	Bavaga 4	Dec-16	<0.1	1.9	<0.1	129	15.6	28.7	-	406	86.6	<0.1	<0.50	85.3	41.5
	Bavaga	Bavaga 5	Dec-16	<0.1	2.48	<0.1	99.9	17.6	26	-	606	67	<0.1	<0.50	93.7	47.6
Low gradient floodplain streams and wetlands	Bavaga	Bavaga 6	Dec-16	<0.1	2.19	<0.1	142	26.7	50.2	-	587	91.4	0.4	<0.50	134	67.6
	Bavaga	Bavaga 7	Dec-16	0.1	2.62	<0.1	168	33.6	59.6	-	941	108	0.4	<0.50	165	94.2
Guideline Value				1	20	1.5	80	-	65	0.15	-	21	-	2	-	200
SQG-High				3.7	70	10	370	-	270	1	-	52	-	25	-	410

Note: Orange highlight indicates exceedance of the guideline value indicating possible ecotoxicological effects. Red highlight indicated exceedance of the SQG-High

Soure: B21261 Wafi ESI. BMT WBM data 12/05/2015
BMT WBM Golpu Project ESIA Aquatic Ecology Assessment, Downstream Impact Assessment and Sediment Transport Assessment

Table C
Surface Water Data - Baseline

BMT WBM total metals/metalloids data																			
Date	**Catchment**	**Site**	**Ag**	**As**	**B**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Hg**	**Mn**	**Mo**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Zn**
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
*Total metals/metalloids **																			
Mar-15	Bavaga	Bavaga US	<0.0001	0.0004	0.006	<0.0001	<0.00005	0.0038	0.0005	0.0018	<0.0001	0.0182	0.0002	0.0019	0.0002	<0.0002	<0.0002	<0.0002	-
Mar-15	Bavaga	Bavaga DS	<0.0001	<0.0002	0.013	<0.0001	<0.00005	0.001	0.0002	<0.0005	<0.0001	0.0131	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Wafi	Nambonga	<0.0001	0.0019	0.008	<0.0001	0.00028	0.0028	0.0033	0.0073	<0.0001	0.272	0.0003	0.0154	0.0039	<0.0002	0.0002	<0.0002	-
Mar-15	Wafi	Zamen	<0.0001	0.0005	0.014	<0.0001	<0.00005	0.0016	0.0004	0.0008	<0.0001	0.0099	0.0004	0.001	0.0002	<0.0002	<0.0002	<0.0002	-
Mar-15	Wafi	Wafi @ Pekumbe	<0.0001	0.0008	0.008	<0.0001	0.00032	0.0015	0.0005	0.0012	<0.0001	0.0332	0.0004	0.0021	0.0005	<0.0002	<0.0002	<0.0002	-
Mar-15	Waime	Waime DS	<0.0001	0.0012	<0.005	<0.0001	<0.00005	0.0028	0.001	0.0024	<0.0001	0.065	0.0003	0.002	0.0008	<0.0002	<0.0002	<0.0002	-
Mar-15	Banir	Banir	<0.0001	0.0004	0.026	<0.0001	<0.00005	0.0024	0.001	0.0037	<0.0001	0.0474	0.0004	0.0029	0.0004	<0.0002	<0.0002	<0.0002	-
Mar-15	Banir	Denti	<0.0001	0.0005	<0.005	<0.0001	<0.00005	0.0003	<0.0001	0.0006	<0.0001	0.0022	<0.0001	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Womul DS/ Chaunong US	<0.0001	0.0011	0.01	<0.0001	<0.00005	0.0003	0.0002	<0.0005	<0.0001	0.134	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Waime US @ Gingen	<0.0001	0.0007	<0.005	<0.0001	<0.00005	0.0007	0.0003	0.0007	<0.0001	0.014	0.0003	<0.0005	0.0002	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Ziriruk @ Z1	0.0002	0.0003	<0.005	<0.0001	<0.00005	0.0008	0.0004	0.0026	<0.0001	0.0244	<0.0001	<0.0005	0.0003	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Womul @ W1	<0.0001	0.0005	0.008	<0.0001	<0.00005	0.0005	0.0001	<0.0005	<0.0001	0.0065	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Bobul Xing	<0.0001	0.0118	0.014	<0.0001	<0.00005	0.0016	0.0008	0.0026	<0.0001	0.185	0.0006	0.0015	0.0013	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Bali Oxbow	<0.0001	0.0051	0.027	<0.0001	<0.00005	<0.0002	0.0001	<0.0005	<0.0001	0.247	<0.0001	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Uruf Oxbow	<0.0001	0.0072	0.012	<0.0001	<0.00005	0.0002	0.0001	<0.0005	<0.0001	0.0841	0.0004	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	-
Mar-15	Lower Watut	Watut @ Maralina	0.0004	0.0129	0.016	0.0001	0.0001	0.0096	0.0048	0.0135	<0.0001	0.376	0.0005	0.0072	0.0096	0.0004	0.0002	<0.0002	-
Mar-15	Lower Watut	Watut @ Uruf	0.0001	0.0116	0.017	0.0001	0.00007	0.0103	0.0047	0.0136	<0.0001	0.357	0.0005	0.0082	0.0093	0.0003	0.0002	<0.0002	-
Mar-15	Lower Watut floodplain	Watut @ Maus Watut	0.0002	0.0177	0.015	0.0002	0.00013	0.0157	0.0079	0.0224	<0.0001	0.633	0.0006	0.013	0.0148	0.0004	0.0003	<0.0002	-
Jun-15	Lower Watut floodplain	Boganchong US	<0.0001	0.0007	<0.005	<0.0001	<0.00005	<0.0002	0.0002	0.0005	<0.0001	0.0306	<0.0001	<0.0005	<0.0001	<0.0002	0.0008	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Wassing	<0.0001	0.0009	<0.005	<0.0001	<0.00005	<0.0002	<0.0001	0.0006	<0.0001	0.0024	0.0002	<0.0005	<0.0001	0.0004	<0.0002	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Wadgink	<0.0001	0.0006	<0.005	<0.0001	<0.00005	<0.0002	<0.0001	<0.0005	<0.0001	0.0055	<0.0001	<0.0005	<0.0001	0.0003	<0.0002	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Swamp@Bambufo	<0.0001	0.0101	0.021	<0.0001	0.00228	<0.0002	0.0004	0.001	<0.0001	1.15	0.0007	0.0007	0.0003	0.0003	<0.0002	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Swamp@Unknown	<0.0001	0.0065	0.031	<0.0001	<0.00005	<0.0002	<0.0001	<0.0005	<0.0001	0.119	0.0008	<0.0005	<0.0001	0.0002	0.0002	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Chaunong DS	<0.0001	0.0105	0.008	<0.0001	<0.00005	0.003	0.0018	0.0053	<0.0001	0.241	0.0002	0.0028	0.0045	0.0003	0.001	<0.0002	0.014
Jun-15	Lower Watut floodplain	Mari	<0.0001	0.0021	0.016	<0.0001	<0.00005	<0.0002	0.0002	0.0007	<0.0001	0.216	0.0004	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	<0.005
Jun-15	Lower Watut floodplain	Boganchong DS	<0.0001	0.0014	<0.005	<0.0001	<0.00005	<0.0002	0.0001	<0.0005	<0.0001	0.234	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	<0.005
Dec-16	Bavaga	Bavaga 1	<0.0001	0.0004	<0.005	<0.0001	<0.00005	0.0009	<0.0001	<0.0005	<0.0001	0.0036	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	<0.0001
Dec-16	Bavaga	Bavaga 2 (= Bavaga US)	<0.0001	0.0003	<0.005	<0.0001	<0.00005	0.0006	<0.0001	0.0005	<0.0001	0.0012	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	<0.0001
Dec-16	Bavaga	Bavaga 3	<0.0001	0.0002	<0.005	<0.0001	<0.00005	0.0019	0.0001	0.0008	<0.0001	0.0047	0.0001	0.0009	<0.0001	<0.0002	<0.0002	<0.0002	0.002
Dec-16	Bavaga	Bavaga 4	<0.0001	0.0002	<0.005	<0.0001	<0.00005	0.001	<0.0001	0.0007	<0.0001	0.0013	0.0001	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	0.003
Dec-16	Bavaga	Bavaga 5 (= Bavaga DS)	<0.0001	0.0002	<0.005	<0.0001	<0.00005	0.001	0.0002	0.0009	<0.0001	0.0182	0.0002	0.0006	<0.0001	<0.0002	0.0002	<0.0002	0.002
Dec-16	Bavaga	Bavaga 6	<0.0001	<0.0002	<0.005	<0.0001	<0.00005	0.0006	<0.0001	0.0006	<0.0001	0.018	0.0002	<0.0005	<0.0001	<0.0002	<0.0002	<0.0002	0.001
Dec-16	Bavaga	Bavaga 7	<0.0001	0.0003	<0.005	<0.0001	<0.00005	0.0012	0.0002	0.0007	<0.0001	0.089	0.0002	0.001	<0.0001	<0.0002	<0.0002	<0.0002	0.001

Source: Aquatic Ecology Assessment, Downstream Impact Assessment, Sediment Characterisation and Transport Assessment - Appendix G

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A10		0.002	0.0001	0.018	0.002	0.0001		0.001	0.005		0.01	0.032
Wafi River catchment	A10		0.001	0.0001	0.001	0.002	0.0001		0.015	0.015		0.01	0.027
Wafi River catchment	A10		0.018	0.0001	0.026	0.015	0.0001		0.001	0.012		0.01	0.064
Wafi River catchment	A10		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.006
Wafi River catchment	A10		0.001	0.0001	0.002	0.001	0.0001		0.002	0.001		0.01	0.006
Wafi River catchment	A10		0.004	0.0001	0.001	0.04	0.0001		0.029	0.001		0.01	0.008
Wafi River catchment	A10		0.001	0.0001	0.064	0.002	0.0001		0.002	0.02		0.01	0.058
Wafi River catchment	A10		0.001	0.0001	0.001	0.001	0.0001		0.002	0.01		0.01	0.005
Wafi River catchment	A10		0.001	0.0001	0.001	0.002	0.0001		0.002	0.01		0.01	0.006
Wafi River catchment	A10		0.001	0.0001	0.001	0.002	0.0001		0.045	0.01		0.01	0.005
Wafi River catchment	A10		0.01	0.0001	0.01	0.033	0.0001		0.002	0.001		0.01	0.01
Wafi River catchment	A10		0.01	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	0.02
Wafi River catchment	A10		0.01	0.0001	0.1	0.001	0.0001		0.002	0.005		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.01	0.002			0.002	0.001		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.01	0.001			0.002	0.001		0.01	0.02
Wafi River catchment	A10		0.004	0.0001	0.01	0.01			0.002	0.003		0.01	0.09
Wafi River catchment	A10		0.002	0.0001	0.01	0.01			0.002	0.002		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.01	0.04			0.01	0.001		0.01	0.01
Wafi River catchment	A10		0.007	0.0001	0.03	0.01			0.01	0.001		0.01	0.03
Wafi River catchment	A10		0.002	0.0001	0.01	0.01			0.07	0.001		0.01	0.01
Wafi River catchment	A10		0.002	0.0001	0.03	0.01			0.01	0.001		0.01	0.02
Wafi River catchment	A10		0.001	0.0001	0.01	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.001	0.001			0.01	0.005		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.001	0.004			0.01	0.001		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.008	0.004			0.03	0.001		0.01	0.01
Wafi River catchment	A10		0.004	0.0001	0.001	0.001			0.01	0.003		0.01	0.01
Wafi River catchment	A10		0.002	0.0001	0.001	0.006			0.03	0.002		0.01	0.01
Wafi River catchment	A10		0.001	0.0006	0.004	0.004			0.001	0.001		0.01	0.01
Wafi River catchment	A10		0.007	0.0001	0.007	0.001			0.001	0.001		0.01	0.03
Wafi River catchment	A10		0.002	0.0001	0.001	0.002			0.006	0.001		0.01	0.04
Wafi River catchment	A10		0.002	0.0001	0.002	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.001	0.001			0.001	0.003		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.001	0.001			0.004	0.018		0.01	0.01
Wafi River catchment	A10		0.001	0.0001	0.001	0.004			0.005	0.001		0.01	0.01
Wafi River catchment	A10		0.002	0.0001	0.008	0.004			0.001	0.001		0.01	0.01
Wafi River catchment	A10		0.008		0.001	0.001			0.003	0.008		0.01	0.01
Wafi River catchment	A10		0.001		0.001	0.006			0.001	0.002		0.01	0.03
Wafi River catchment	A10		0.001		0.004	0.004			0.001	0.004		0.01	0.04
Wafi River catchment	A10		0.014		0.007	0.001			0.001	0.001			0.01
Wafi River catchment	A10		0.002		0.001	0.002			0.006	0.001			0.005
Wafi River catchment	A10		0.004		0.002	0.001			0.001	0.002			0.006
Wafi River catchment	A10		0.002		0.001	0.001			0.001				0.011
Wafi River catchment	A10		0.001		0.001	0.007			0.004				0.01
Wafi River catchment	A10		0.002		0.011	0.038			0.005				0.005
Wafi River catchment	A10				0.096	0.004			0.001				0.016
Wafi River catchment	A10				0.006	0.002			0.003				0.009
Wafi River catchment	A10				0.002	0.013			0.001				0.005
Wafi River catchment	A10				0.009	0.001			0.001				0.005
Wafi River catchment	A10				0.001	0.004			0.01				0.005
Wafi River catchment	A10				0.012	0.001			0.067				0.005
Wafi River catchment	A10				0.001	0.001			0.004				0.006
Wafi River catchment	A10				0.001	0.003			0.002				0.011
Wafi River catchment	A10				0.005				0.007				0.01
Wafi River catchment	A10								0.002				0.005
Wafi River catchment	A10								0.009				0.016
Wafi River catchment	A10								0.001				0.009
Wafi River catchment	A10								0.001				0.005
Wafi River catchment	A10								0.005				0.005
Wafi River catchment	A10												0.005
Wafi River catchment	A10												0.005
Wafi River catchment	A10												0.016
Wafi River catchment	A10												0.086
Wafi River catchment	A10												0.009
Wafi River catchment	A10												0.005
Wafi River catchment	A10												0.029
Wafi River catchment	A10												0.007
Wafi River catchment	A10												0.019
Wafi River catchment	A10												0.005
Wafi River catchment	A10												0.005
Wafi River catchment	A10												0.01
Wafi River catchment	A100		0.001	0.0001	0.007	0.002	0.0001		0.002	0.001		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.002	0.002	0.0001		0.001	0.001		0.01	0.006
Wafi River catchment	A100		0.001	0.0001	0.005	0.001	0.0001		0.005	0.001		0.01	0.007
Wafi River catchment	A100		0.001	0.0001	0.002	0.001	0.0001		0.001	0.001		0.01	0.007
Wafi River catchment	A100		0.001	0.0001	0.002	0.001	0.0001		0.003	0.001		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.002	0.017	0.0001		0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.002	0.002	0.0001		0.003	0.03		0.01	0.016
Wafi River catchment	A100		0.01	3	0.002	0.002	0.0001		0.003	172		0.01	0.008
Wafi River catchment	A100		0.01	1	0.001	0.001	0.0001		0.005	116		0.01	0.008
Wafi River catchment	A100		0.001	0.0002	0.001	0.001	0.0001		0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.002	0.0001	0.01	82	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	180	132	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	172	0.01	0.0001		0.004	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.01	0.002	0.0001		0.002	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.002	0.001	0.0001		0.003	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.001	0.0001		0.003	0.001		0.01	476
Wafi River catchment	A100		0.001	0.0001	0.001	0.001	0.0001		0.004	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.002	0.0001		0.004	0.001		0.01	325
Wafi River catchment	A100		0.002	0.0001	0.001	0.001	0.0015		0.002	0.001		0.01	0.03
Wafi River catchment	A100		0.002	0.0001	0.004	0.001	0.0015		0.002	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.001	0.0002		0.01	0.002		0.01	0.01
Wafi River catchment	A100		0.0065	0.0027	0.001	0.001			0.01	0.0036		0.01	0.01
Wafi River catchment	A100		0.0035	0.00005	0.001	0.001			0.01	0.0071		0.01	0.01
Wafi River catchment	A100		0.0022	0.0005	0.001	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A100		47	0.0002	0.001	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A100		74	0.0001	0.002	0.0233			0.01	0.001		0.0171	0.01
Wafi River catchment	A100		0.001	0.0001	0.0052	0.0022			0.01	0.001		0.0021	0.01
Wafi River catchment	A100		48	0.0001	0.0104	0.0011			0.01	0.001		0.0002	0.01
Wafi River catchment	A100		0.001	0.0001	0.0021	0.002			0.004	0.001		0.01	0.01
Wafi River catchment	A100		0.002	0.0001	0.002	0.001			0.002	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.002			0.002	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A100		0.001	0.0001	0.004	0.001			0.002	0.001		0.01	0.009
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.002		0.01	0.005
Wafi River catchment	A100		0.002	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.002	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.0033	0.026		0.01	0.005
Wafi River catchment	A100		0.001	3	0.002	0.001			0.0034	172		0.01	0.008
Wafi River catchment	A100		0.001	0.0002	0.001	0.001			0.002	0.004		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.004	0.001		0.01	0.005
Wafi River catchment	A100		0.003	0.0001	0.001	0.003			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	1	0.007	82			0.001	116		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	180	0.001			0.001	0.001		0.01	0.0212
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.0111

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.0008
Wafi River catchment	A100		0.001	0.0001	0.001	132			0.002	0.001		0.01	0.009
Wafi River catchment	A100		0.001	0.0001	172	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.01	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.01	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.006	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.001	0.003			0.004	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.004	0.002			0.006	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.00005	0.003	0.001			0.001	0.0002		0.01	0.005
Wafi River catchment	A100		0.0007	0.0003	0.001	0.001			0.001	0.0001		0.01	0.005
Wafi River catchment	A100		0.0021	0.0005	0.001	0.001			0.002	0.0004		0.0007	0.005
Wafi River catchment	A100		0.0001	0.00005	0.001	0.001			0.001	0.0015		0.0127	0.005
Wafi River catchment	A100		0.001	0.00005	0.001	0.0026			0.005	0.0005		0.0001	0.005
Wafi River catchment	A100		0.0001	0.0027	0.0016	0.0006			0.002	0.0036		0.0058	0.008
Wafi River catchment	A100		0.0065	0.00005	0.0046	0.0109			0.005	0.0071		0.0001	476
Wafi River catchment	A100		0.0035	0.0005	0.0122	0.0038			0.005	0.001		0.0171	0.005
Wafi River catchment	A100		0.0022	0.0001	0.0068	0.0008			0.002	0.001		0.0021	0.005
Wafi River catchment	A100		0.001	0.0001	0.0001	0.0233			0.002	0.001		0.0002	325
Wafi River catchment	A100		0.001	0.0001	0.0052	0.0022			0.005	0.001		0.01	0.027
Wafi River catchment	A100		0.001	0.0001	0.0104	0.0011			0.004	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.0021	0.001			0.002	0.001		0.01	0.006
Wafi River catchment	A100		0.001	0.0001	0.002	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.003	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A100		0.003	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.0005	0.001		0.01	0.005
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.0266	0.001		0.01	0.008
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.0042	0.001		0.01	0.007
Wafi River catchment	A100		0.002	0.0001	0.001	0.001			0.0853	0.001		0.01	0.006
Wafi River catchment	A100		0.001	0.0001	0.001	0.001			0.0075	0.001		0.01	0.005
Wafi River catchment	A100		0.001		0.001	0.001			0.0033			0.01	0.005
Wafi River catchment	A100				0.001	0.001			0.0034			0.01	0.005
Wafi River catchment	A100				0.001	0.001			0.002				0.005
Wafi River catchment	A100				0.001	0.001			0.002				0.0046
Wafi River catchment	A100				0.001				0.003				0.000025
Wafi River catchment	A100								0.001				0.0206
Wafi River catchment	A100								0.001				0.074
Wafi River catchment	A100								0.001				0.0008
Wafi River catchment	A100								0.002				0.0212
Wafi River catchment	A100								0.002				0.0111
Wafi River catchment	A100								0.002				0.0008
Wafi River catchment	A100								0.002				0.005
Wafi River catchment	A100								0.002				0.007
Wafi River catchment	A100								0.001				0.005
Wafi River catchment	A100								0.001				0.005
Wafi River catchment	A100								0.002				0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A100												0.005
Wafi River catchment	A105		0.001	0.0001	0.005	0.004	0.0001		0.014	0.001		0.01	0.025
Wafi River catchment	A105		0.002	0.0001	0.001	0.001	0.0001		0.001	0.002		0.01	0.03
Wafi River catchment	A105		0.002	0.0002	0.002	0.005	0.0001		0.012	0.002		0.01	0.068
Wafi River catchment	A105		0.002	0.0002	0.005	0.003	0.0001		0.011	0.002		0.01	0.043
Wafi River catchment	A105		0.002	0.0001	0.006	0.003	0.0001		0.01	0.002		0.01	0.02
Wafi River catchment	A105		0.002	0.0002	0.007	0.002	0.0001		0.007	0.001		0.01	0.039
Wafi River catchment	A105		0.002	0.0001	0.001	0.004	0.0001		0.01	0.001		0.01	0.024
Wafi River catchment	A105		0.002	0.0001	0.001	0.004	0.0001		0.001	0.004		0.01	0.025
Wafi River catchment	A105		0.002	0.0003	0.001	0.001	0.0001		0.005	0.006		0.01	0.053
Wafi River catchment	A105		0.002	0.0004	0.002	0.007	0.0001		0.008	0.008		0.01	0.082
Wafi River catchment	A105		0.003	0.0007	0.004	0.001	0.0001		0.019	0.005		0.01	0.103
Wafi River catchment	A105		0.002	0.0003	0.001	0.017	0.0001		0.021	0.003		0.01	0.041
Wafi River catchment	A105		0.002	0.0003	0.01	0.018	0.0001		0.031	0.002		0.01	0.052
Wafi River catchment	A105		0.002	0.0002	0.02	0.009			0.018	0.002		0.01	0.036
Wafi River catchment	A105		0.002	0.0002	0.01	0.004			0.017	0.002		0.01	0.05
Wafi River catchment	A105		0.002	0.0002	0.01	0.003			0.011	0.004		0.01	0.036
Wafi River catchment	A105		0.002	0.0002	0.01	0.004			0.016	0.004		0.01	0.026
Wafi River catchment	A105		0.003	0.0004	0.01	0.003			0.011	0.001		0.01	0.065
Wafi River catchment	A105		0.001	0.0004	0.002	0.003			0.017	0.01		0.01	0.054
Wafi River catchment	A105		0.01	0.0002	0.002	0.009			0.019	0.01		0.01	0.026
Wafi River catchment	A105		0.003	0.0002	0.001	0.01			0.018	0.01		0.01	0.02
Wafi River catchment	A105		0.002	0.0002	0.004	0.003			0.017	0.01		0.01	0.02
Wafi River catchment	A105		0.004	0.0002	0.001	0.01			0.01	0.01		0.01	0.05
Wafi River catchment	A105		0.002	0.0003	0.001	0.01			0.01	0.001		0.01	0.03
Wafi River catchment	A105		0.01	0.0002	0.001	0.01			0.01	0.001		0.01	0.03
Wafi River catchment	A105		0.002	0.0003	0.002	0.01			0.01	0.002			0.04
Wafi River catchment	A105		0.002	0.0003	0.004	0.01			0.01	0.004			0.05
Wafi River catchment	A105		0.002	0.0002	0.008	0.01			0.02	0.002			0.05
Wafi River catchment	A105		0.002	0.0002	0.002	0.01			0.02	0.003			0.01
Wafi River catchment	A105		0.003	0.0004	0.002	0.01			0.01	0.003			0.05
Wafi River catchment	A105		0.003	0.0002	0.001	0.01			0.04	0.003			0.04
Wafi River catchment	A105		0.002	0.0002	0.004	0.01			0.02	0.003			0.05
Wafi River catchment	A105		0.004	0.0002	0.001	0.01			0.02	0.004			0.04
Wafi River catchment	A105		0.002	0.0003	0.001	0.01			0.02	0.001			0.04
Wafi River catchment	A105		0.01	0.0002	0.001	0.01			0.01	0.001			0.06
Wafi River catchment	A105		0.002	0.0003	0.002	0.01			0.02	0.002			0.06
Wafi River catchment	A105		0.002	0.0003	0.004	0.01			0.02	0.004			0.07
Wafi River catchment	A105		0.002	0.0002	0.008	0.01			0.02	0.002			0.05
Wafi River catchment	A105		0.002	0.0002	0.001	0.01			0.02	0.003			0.04
Wafi River catchment	A105		0.003	0.0004	0.001	0.02			0.02	0.003			0.05
Wafi River catchment	A105		0.002	0.0003		0.01			0.01	0.003			0.05
Wafi River catchment	A105		0.004	0.0003		0.01			0.01	0.003			0.05
Wafi River catchment	A105					0.01			0.02	0.004			0.04
Wafi River catchment	A105					0.01			0.02	0.002			0.03
Wafi River catchment	A105					0.01			0.02	0.003			0.04
Wafi River catchment	A105					0.01			0.02				0.04
Wafi River catchment	A105					0.01			0.02				0.06
Wafi River catchment	A105					0.01			0.01				0.06
Wafi River catchment	A105					0.01			0.02				0.07
Wafi River catchment	A105					0.02			0.02				0.05
Wafi River catchment	A105					0.01			0.02				0.04
Wafi River catchment	A105					0.01			0.02				0.05
Wafi River catchment	A105					0.01			0.01				0.05
Wafi River catchment	A105					0.004			0.01				0.05
Wafi River catchment	A105					0.005			0.02				0.04
Wafi River catchment	A105					0.006			0.02				0.03
Wafi River catchment	A105					0.003			0.02				0.04
Wafi River catchment	A105					0.005			0.02				0.04
Wafi River catchment	A105					0.006			0.02				0.017
Wafi River catchment	A105					0.005			0.01				0.022
Wafi River catchment	A105					0.005			0.01				0.045

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A105					0.005			0.009				0.028
Wafi River catchment	A105					0.012			0.012				0.027
Wafi River catchment	A105					0.004			0.009				0.044
Wafi River catchment	A105					0.005			0.011				0.049
Wafi River catchment	A105					0.006			0.015				0.048
Wafi River catchment	A105					0.003			0.015				0.014
Wafi River catchment	A105					0.005			0.012				0.054
Wafi River catchment	A105					0.006			0.042				0.017
Wafi River catchment	A105					0.005			0.022				0.022
Wafi River catchment	A105					0.005			0.01				0.045
Wafi River catchment	A105					0.005			0.009				0.028
Wafi River catchment	A105					0.012			0.012				0.027
Wafi River catchment	A105					0.007			0.009				0.044
Wafi River catchment	A105					0.005			0.011				0.049
Wafi River catchment	A105								0.015				0.048
Wafi River catchment	A105								0.015				0.014
Wafi River catchment	A105								0.012				0.054
Wafi River catchment	A105								0.042				0.042
Wafi River catchment	A105								0.022				0.052
Wafi River catchment	A105								0.017				
Wafi River catchment	A105								0.016				
Wafi River catchment	A110		0.001	0.0001	0.001	0.01	0.0001		0.002	0.001		0.01	0.01
Wafi River catchment	A110		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A110		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A110		0.001	0.0001	0.005	0.001	0.0001		0.002	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.002	0.001	0.0001		0.001	0.002		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A110		5	0.0001	0.001	0.001			0.001	0.001		0.01	0.017
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.005	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.002	0.001			0.001	0.002		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0006	0.001	0.001			0.001	0.012		0.01	0.017
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	1	158	0.001			0.001	9		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	180			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	212
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.002	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001				0.001		0.01	0.005
Wafi River catchment	A110		0.001	0.0001	0.001	0.001				0.001			0.005
Wafi River catchment	A110					0.001							0.018
Wafi River catchment	A110												0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.089	0.0001		0.002	0.002		0.01	0.053
Wafi River catchment	A120		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.002	0.001	0.0001		0.001	0.001		0.01	0.021
Wafi River catchment	A120		0.001	0.0001	0.003	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.089			0.002	0.002		0.01	0.053
Wafi River catchment	A120		5	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.021
Wafi River catchment	A120		0.001	0.0001	0.003	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0008	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.029	0.001		0.01	93
Wafi River catchment	A120		0.001	1	190	80			0.001	6		0.01	0.063
Wafi River catchment	A120		0.001	0.0008	0.001	0.002			0.001	0.004		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A120		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A120		0.001	0.0001	0.001	0.001				0.001		0.01	0.007
Wafi River catchment	A120		0.001	0.0001	0.001	0.001				0.001			
Wafi River catchment	A125		0.001	0.0005	0.01	0.004	0.0001		0.006	0.002		0.01	0.007
Wafi River catchment	A125		0.001	0.0002	0.009	0.002	0.0001		0.007	0.004		0.01	0.062
Wafi River catchment	A125		0.001	0.0002	0.004	0.004	0.0001		0.002	0.004		0.01	0.011
Wafi River catchment	A125		0.001	0.0001	0.003	0.005	0.0001		0.004	0.01		0.01	0.084
Wafi River catchment	A125		0.001	0.0001	0.002	0.002	0.0001		0.023	0.002		0.01	0.018
Wafi River catchment	A125		0.002	0.0001	0.031	0.01	0.0001		0.02	0.002		0.01	0.068
Wafi River catchment	A125		0.002	0.0001	0.11	0.01	0.0001		0.074	0.001		0.01	0.006
Wafi River catchment	A125		0.002	0.0001	0.008	0.031	0.0001		0.006	0.009		0.01	0.036
Wafi River catchment	A125		0.001	0.0001	0.001	0.003	0.0001		0.011	0.001		0.01	0.036
Wafi River catchment	A125		0.002	0.0001	0.001	0.003	0.0001		0.011	0.01		0.01	0.005
Wafi River catchment	A125		0.002	0.0001	0.002	0.003	0.0001		0.002	0.001		0.01	0.026
Wafi River catchment	A125		0.002	0.0001	0.027	0.001	0.0001		0.018	0.001		0.01	0.005
Wafi River catchment	A125		0.006	0.0001	0.001	0.011	0.0001		0.001	0.001		0.01	0.03
Wafi River catchment	A125		0.001	0.0001	0.03	0.001			0.02	0.008		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.01	0.01			0.01	0.001		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.01	0.01			0.01	0.001		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.01	0.02			0.01	0.001		0.01	0.01
Wafi River catchment	A125		0.004	0.0001	0.001	0.02			0.001	0.001		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A125		0.003	0.0001	0.034	0.001			0.021	0.001		0.01	0.01
Wafi River catchment	A125		0.002	0.0001	0.002	0.01			0.001	0.001		0.01	0.005
Wafi River catchment	A125		0.002	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A125		0.002	0.0001	0.001	0.001			0.001	0.008		0.01	0.005
Wafi River catchment	A125		0.002	0.0001	0.001	0.001			0.001	0.001		0.01	0.029
Wafi River catchment	A125		0.002	0.0001	0.001	0.001			0.001	0.001			0.005
Wafi River catchment	A125		0.002	0.0001	0.002	0.001			0.002	0.001			0.005
Wafi River catchment	A125		0.004	0.0001	0.001	0.002			0.001	0.001			0.009
Wafi River catchment	A125		0.002		0.001	0.001			0.001	0.001			0.007
Wafi River catchment	A125		0.002		0.001	0.001			0.001	0.001			0.005
Wafi River catchment	A125		0.003		0.034	0.001			0.021	0.001			0.005
Wafi River catchment	A125		0.002		0.002	0.01			0.001	0.001			0.005
Wafi River catchment	A125		0.002		0.001	0.002			0.001				0.005
Wafi River catchment	A125		0.002		0.001	0.001			0.001				0.005
Wafi River catchment	A125		0.002		0.001	0.001			0.001				0.029
Wafi River catchment	A125		0.002		0.001	0.001			0.001				0.005
Wafi River catchment	A125				0.002	0.001			0.002				0.005
Wafi River catchment	A125				0.001	0.002			0.001				0.009
Wafi River catchment	A125				0.001	0.001			0.001				0.007
Wafi River catchment	A125					0.001							0.005
Wafi River catchment	A125												0.005
Wafi River catchment	A125												0.005
Wafi River catchment	A125												0.005

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A13		0.001	0.0001	0.007	0.004	0.0001		0.007	0.002		0.01	0.009
Wafi River catchment	A13		0.001	0.0001	0.007	0.001	0.0001		0.01	0.002		0.01	0.018
Wafi River catchment	A13		0.002	0.0002	0.001	0.005	0.0001		0.006	0.001		0.01	0.051
Wafi River catchment	A13		0.002	0.0004	0.001	0.003	0.0001		0.006	0.002		0.01	0.028
Wafi River catchment	A13		0.001	0.0002	0.001	0.002	0.0001		0.003	0.007		0.01	0.008
Wafi River catchment	A13		0.002	0.0001	0.001	0.001	0.0001		0.002	0.004		0.01	0.038
Wafi River catchment	A13		0.003	0.0002	0.013	0.005	0.0001		0.002	0.002		0.01	0.009
Wafi River catchment	A13		0.003	0.0002	0.018	0.001	0.0001		0.014	0.001		0.01	0.066
Wafi River catchment	A13		0.001	0.0001	0.002	0.017	0.0001		0.003	0.006		0.01	0.033
Wafi River catchment	A13		0.002	0.0001	0.003	0.013	0.0001		0.024	0.002		0.01	0.006
Wafi River catchment	A13		0.001	0.0001	0.026	0.002	0.0001		0.014	0.01		0.01	0.005
Wafi River catchment	A13		0.004	0.0001	0.002	0.005	0.0001		0.002	0.001		0.01	0.018
Wafi River catchment	A13		0.002	0.0002	0.02	0.01			0.002	0.001		0.01	0.005
Wafi River catchment	A13		0.002	0.0001	0.01	0.014			0.002	0.001		0.01	0.044
Wafi River catchment	A13		0.001	0.0001	0.01	0.005			0.005	0.001		0.01	0.016
Wafi River catchment	A13		0.001	0.0001	0.01	0.01			0.002	0.002		0.01	0.044
Wafi River catchment	A13		0.001	0.0001	0.01	0.01			0.014	0.001		0.01	0.044
Wafi River catchment	A13		0.002	0.0001	0.001	0.01			0.005	0.001		0.01	0.01
Wafi River catchment	A13		0.001	0.0001	0.002	0.01			0.024	0.001		0.01	0.03
Wafi River catchment	A13		0.001	0.0001	0.001	0.01			0.014	0.001		0.01	0.02
Wafi River catchment	A13		0.001	0.0001	0.001	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A13		0.001	0.0002	0.001	0.001			0.01	0.001		0.01	0.02
Wafi River catchment	A13		0.002	0.0001	0.001	0.002			0.02	0.001		0.01	0.01
Wafi River catchment	A13		0.001	0.0001	0.001	0.001			0.01	0.001			0.03
Wafi River catchment	A13		0.001	0.0001	0.002	0.004			0.01	0.002			0.01
Wafi River catchment	A13		0.001	0.0001	0.001	0.001			0.01	0.001			0.01
Wafi River catchment	A13		0.002	0.0001	0.001	0.001			0.01	0.001			0.02
Wafi River catchment	A13		0.001	0.0001	0.002	0.001			0.01	0.001			0.03
Wafi River catchment	A13		0.001		0.001	0.001			0.01	0.001			0.01
Wafi River catchment	A13		0.001		0.001	0.001			0.01	0.001			0.03
Wafi River catchment	A13		0.001		0.001	0.001			0.01	0.001			0.01
Wafi River catchment	A13		0.001		0.001	0.002			0.01				0.02
Wafi River catchment	A13		0.002		0.001	0.001			0.01				0.02
Wafi River catchment	A13				0.002	0.004			0.01				0.03
Wafi River catchment	A13				0.001	0.001			0.01				0.03
Wafi River catchment	A13				0.001	0.001			0.01				0.01
Wafi River catchment	A13				0.001	0.001			0.01				0.01
Wafi River catchment	A13					0.001			0.01				0.02
Wafi River catchment	A13					0.001			0.01				0.03
Wafi River catchment	A13					0.002			0.01				0.01
Wafi River catchment	A13								0.01				0.03
Wafi River catchment	A13								0.001				0.01
Wafi River catchment	A13								0.002				0.02
Wafi River catchment	A13								0.001				0.02
Wafi River catchment	A13								0.001				0.03
Wafi River catchment	A13								0.01				0.03
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.002				0.011
Wafi River catchment	A13								0.002				0.005
Wafi River catchment	A13								0.001				0.032
Wafi River catchment	A13								0.002				0.016
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.01				0.005
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.001				0.005
Wafi River catchment	A13								0.002				0.011
Wafi River catchment	A13								0.002				0.005
Wafi River catchment	A13								0.001				0.032
Wafi River catchment	A13								0.006				0.016
Wafi River catchment	A13												0.005
Wafi River catchment	A13												0.005
Wafi River catchment	A13												0.005
Wafi River catchment	A13												0.005
Wafi River catchment	A13												0.018
Wafi River catchment	A130		0.001	0.0002	0.003	0.001	0.0001		0.002	0.001		0.01	0.007
Wafi River catchment	A130		0.001	0.0001	0.004	0.003	0.0001		0.002	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.004	0.002	0.0001		0.003	11		0.01	0.005
Wafi River catchment	A130		0.001	1	0.001	0.001	0.0001		0.002	0.001		0.01	0.03
Wafi River catchment	A130		0.001	0.0001	0.003	0.001	0.0001		0.002	0.001		0.01	0.01
Wafi River catchment	A130		0.001	0.0001	0.001	101	0.0001		0.001	0.001		0.01	131
Wafi River catchment	A130		0.001	0.0001	106	0.17	0.0001		0.002	0.001		0.01	0.01
Wafi River catchment	A130		0.002	0.001	0.002	0.005	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A130		0.001	0.0001	0.002	0.001	0.0001		0.001	0.01		0.01	0.01
Wafi River catchment	A130		0.001	0.001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A130		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A130		0.002	0.0001	0.001	0.002	0.0001		0.01	0.001		0.01	0.01
Wafi River catchment	A130		0.001	0.0001	0.01	0.01	0.0001		0.001	0.001		0.01	0.19
Wafi River catchment	A130		0.001	0.0001	0.004	0.001	0.001		0.001	0.001		0.01	0.009
Wafi River catchment	A130		0.01	0.0001	0.001	0.001	0.0019		0.001	0.0031		0.1	0.005
Wafi River catchment	A130		0.001	0.0019	0.001	0.001	0.0002		0.001	0.024		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.0002		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.0014	0.001		0.01	0.005
Wafi River catchment	A130		0.002	0.0001	0.0025	0.0112			0.002	0.001		0.01	0.052
Wafi River catchment	A130		0.001	0.0001	0.014	0.0038			0.004	0.001		0.01	0.005
Wafi River catchment	A130		0.0071	0.0001	0.0061	0.0031			0.002	0.001		0.0001	0.005
Wafi River catchment	A130		0.0022	0.001	0.002	0.005			0.001	0.001		0.0025	0.005
Wafi River catchment	A130		0.0027	0.0001	0.002	0.001			0.001	0.01		0.0002	0.005
Wafi River catchment	A130		10	0.001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.0136
Wafi River catchment	A130		6	0.0001	0.001	0.002			0.01	0.001		0.01	0.0125
Wafi River catchment	A130		0.001	0.0001	0.01	0.01			0.001	0.001		0.01	0.0004
Wafi River catchment	A130		0.002	0.0001	0.004	0.001			0.001	0.001		0.01	0.009
Wafi River catchment	A130		0.002	0.0001	0.001	0.001			0.001	0.001		0.1	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.01	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.052
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	11		0.01	0.005
Wafi River catchment	A130		0.002	1	0.003	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	106	101			0.002	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0002	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.032
Wafi River catchment	A130		0.001	0.0001	0.003	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.002	0.0001	0.001	0.003			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	131
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.003	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.002	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.001	0.0016		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.0005	0.0001		0.01	0.005

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A130		0.001	0.0001	0.001	0.001			0.0005	0.0001		0.01	0.005
Wafi River catchment	A130		0.001	0.0005	0.001	0.001			0.0307	0.0016		0.01	0.005
Wafi River catchment	A130		0.001	0.0024	0.0001	0.0003			0.0038	0.0001		0.01	0.005
Wafi River catchment	A130		0.001	0.0001	0.0086	0.0001			0.0076	0.0067		0.0001	0.005
Wafi River catchment	A130		0.001	0.0016	0.0121	0.0006			0.0049	0.0031		0.0001	0.005
Wafi River catchment	A130		0.0005	0.0019	0.006	0.0152			0.0014	0.024		0.0069	0.005
Wafi River catchment	A130		0.0007	0.0001	0.0001	0.0126			0.002	0.0002		0.0001	0.005
Wafi River catchment	A130		0.0036	0.0001	0.0025	0.0074			0.004			0.0067	0.0197
Wafi River catchment	A130		0.0001		0.014	0.0112						0.0001	0.0001
Wafi River catchment	A130		0.0006		0.0061	0.0038						0.0001	0.0034
Wafi River catchment	A130		0.0006			0.0031						0.0025	0.0224
Wafi River catchment	A130		0.0071									0.0002	0.158
Wafi River catchment	A130		0.0022										0.0105
Wafi River catchment	A130		0.0027										0.0136
Wafi River catchment	A130												0.0125
Wafi River catchment	A130												0.0004
Wafi River catchment	A14		0.002	0.0003	0.014	0.011	0.0001		0.009	0.003		0.01	0.01
Wafi River catchment	A14		0.002	0.0003	0.015	0.001	0.0001		0.001	0.006		0.01	0.026
Wafi River catchment	A14		0.001	0.0002	0.001	0.015	0.0001		0.012	0.01		0.01	0.021
Wafi River catchment	A14		0.004	0.0001	0.025	0.001	0.0001		0.001	0.006		0.01	0.005
Wafi River catchment	A14		0.002	0.0001	0.015	0.002	0.0001		0.002	0.001		0.01	0.013
Wafi River catchment	A14		0.001	0.0001	0.002	0.003	0.0001		0.001	0.002		0.01	0.007
Wafi River catchment	A14		0.002	0.0001	0.002	0.03	0.0001		0.004	0.001		0.01	0.042
Wafi River catchment	A14		0.001	0.0001	0.004	0.014	0.0001		0.001	0.001		0.01	0.063
Wafi River catchment	A14		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.011
Wafi River catchment	A14		0.001	0.0001	0.01	0.004	0.0001		0.002	0.01		0.01	0.042
Wafi River catchment	A14		0.001	0.0001	0.01	0.001	0.0021		0.002	0.001		0.01	0.005
Wafi River catchment	A14		0.001	0.0001	0.02	0.002	0.0001		0.02	0.001		0.01	0.005
Wafi River catchment	A14		0.001	0.0001	0.01	0.004	0.0001		0.024	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0003	0.01	0.001			0.005	0.001		0.01	0.005
Wafi River catchment	A14		0.001	0.0001	0.02	0.01			0.013	0.001		0.01	0.02
Wafi River catchment	A14		0.001	0.0001	0.001	0.01			0.002	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.01			0.001	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.01			0.003	0.005		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.004	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.002	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0003	0.004	0.001			0.01	0.001		0.01	0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.02
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.001	0.001			0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.002			0.001	0.001			0.01
Wafi River catchment	A14		0.001	0.0001	0.001	0.001			0.001	0.005			0.01
Wafi River catchment	A14		0.001		0.001	0.001			0.001	0.001			0.01
Wafi River catchment	A14		0.001		0.001	0.001			0.001	0.001			0.01
Wafi River catchment	A14		0.001		0.002	0.001			0.001	0.001			0.02
Wafi River catchment	A14		0.001		0.001	0.001			0.001	0.001			0.005
Wafi River catchment	A14				0.001	0.001			0.003				0.005
Wafi River catchment	A14				0.004	0.001			0.001				0.018
Wafi River catchment	A14				0.001	0.001			0.001				0.005
Wafi River catchment	A14				0.001	0.001			0.001				0.005
Wafi River catchment	A14				0.001	0.002			0.001				0.006
Wafi River catchment	A14					0.001			0.001				0.006
Wafi River catchment	A14					0.001			0.001				0.005
Wafi River catchment	A14					0.001			0.001				0.005
Wafi River catchment	A14								0.001				0.011
Wafi River catchment	A14								0.001				0.005
Wafi River catchment	A14								0.003				0.005
Wafi River catchment	A14								0.001				0.018
Wafi River catchment	A14								0.001				0.005
Wafi River catchment	A14								0.001				0.005
Wafi River catchment	A14												0.006
Wafi River catchment	A14												0.006
Wafi River catchment	A14												0.005
Wafi River catchment	A14												0.005
Wafi River catchment	A14												0.011
Wafi River catchment	A14												0.005
Wafi River catchment	A14												0.005
Wafi River catchment	A15		0.008	0.0064	0.06	0.226	0.0001		0.336	0.04		0.01	1.18
Wafi River catchment	A15		0.008	0.0064	0.06	0.226			0.336	0.04		0.01	1.18
Wafi River catchment	A16		0.003	0.0086	0.034	0.145	0.0001		0.565	0.041		0.01	2.72
Wafi River catchment	A16		0.003	0.0086	0.034	0.145			0.565	0.041		0.01	2.72
Wafi River catchment	A17		0.002	0.0034	0.009	0.104	0.0001		0.198	0.015		0.01	0.551
Wafi River catchment	A17		0.002	0.0034	0.009	0.104			0.198	0.015		0.01	0.551
Wafi River catchment	A18		0.002	0.002	0.004	0.018	0.0001		0.137	0.018		0.01	0.384
Wafi River catchment	A18		0.002	0.002	0.004	0.018			0.137	0.018		0.01	0.384
Wafi River catchment	A19		0.002	0.0001	0.015	0.01	0.0001		0.01	0.003		0.01	0.017
Wafi River catchment	A19		0.001	1	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.01	0.0001	0.04	0.03	0.0001		0.04	0.02		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	59	52	0.0001		0.01	11		0.01	0.08
Wafi River catchment	A19		0.001	0.0001	0.02	0.01	0.0001		0.01	0.001		0.01	70
Wafi River catchment	A19		0.001	0.0001	0.02	0.01	0.0001		0.01	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0004	0.001	0.01	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A19		0.014	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.001	0.0001		0.001	0.02		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.04	0.002	0.0001		0.038	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.029	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.02
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A19		6	0.0001	0.001	0.001			0.001	0.001		0.01	0.02
Wafi River catchment	A19		14	0.0001	0.004	0.001			0.003	0.001		0.01	0.01
Wafi River catchment	A19		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.06
Wafi River catchment	A19		0.001	0.0004	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.02		0.01	0.005
Wafi River catchment	A19		0.014	0.0001	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A19		0.001	0.0001	0.04	0.002			0.038	0.001		0.01	0.075
Wafi River catchment	A19		0.001	0.0001	0.001	0.029			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.004	0.001			0.003	0.001		0.01	0.005
Wafi River catchment	A19		0.001	1	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	11		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	59	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A19		0.001	0.0001	0.001	52			0.001	0.001		0.01	0.075
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.003	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.003	0.004			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.004			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A19		0.001	0.0001	0.003	0.004			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.002	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.002	0.001			0.002	0.001		0.01	70
Wafi River catchment	A19		0.001	0.0001	0.002	0.001			0.002	0.001		0.01	0.006
Wafi River catchment	A19		0.001	1	0.003	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	20		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	84	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	75			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.002			0.002	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A19		0.001	0.0001	0.003	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A19		0.001		0.001	0.002			0.002	0.001		0.01	0.005
Wafi River catchment	A19		0.001		0.003	0.002			0.002	0.001		0.01	0.007
Wafi River catchment	A19				0.002	0.002			0.001			0.01	0.005
Wafi River catchment	A19				0.001	0.001						0.01	0.005
Wafi River catchment	A19					0.001							0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												121
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A19												0.005
Wafi River catchment	A20		0.002	0.0005	0.002	0.001	0.0001		0.017	0.003		0.01	0.055
Wafi River catchment	A20		0.001	0.001	0.002	0.002	0.0001		0.041	0.008		0.01	0.166
Wafi River catchment	A20		0.01	0.0012	0.002	0.002	0.0001		0.051	0.008		0.01	0.224
Wafi River catchment	A20		0.001	0.0008	0.002	0.002	0.0001		0.037	0.007		0.01	0.147
Wafi River catchment	A20		0.009	0.0003	0.016	0.007	0.0001		0.02	0.006		0.01	0.047
Wafi River catchment	A20		0.007	0.0011	0.002	0.003	0.0001		0.041	0.011		0.01	0.185
Wafi River catchment	A20		0.001	0.0006	0.001	0.001	0.0001		0.022	0.002		0.01	0.066
Wafi River catchment	A20		0.001	0.0006	0.001	0.01	0.0001		0.022	0.002		0.01	0.066
Wafi River catchment	A20		0.001	1	0.01	0.01	0.0001		0.06	0.02		0.01	0.22
Wafi River catchment	A20		0.001	0.0017	0.01	0.01	0.0001		0.05	0.01		0.01	0.2
Wafi River catchment	A20		0.001	0.0001	106	96	0.0001		0.06	0.02		0.01	0.23
Wafi River catchment	A20		0.001	0.0018	0.02	0.01	0.0001		0.05	0.02		0.01	0.2
Wafi River catchment	A20		0.001	0.0016	0.01	0.01	0.0001		0.03	0.02		0.01	0.09
Wafi River catchment	A20		0.001	0.0016	0.01	0.01			0.05	0.02		0.01	0.21
Wafi River catchment	A20		0.001	0.0001	0.01	0.01			0.05	0.02		0.01	0.21
Wafi River catchment	A20		37	0.0017	0.003	0.01			0.01	0.01		0.01	0.01
Wafi River catchment	A20		0.001	0.0012	0.01	0.004			0.05	0.01		0.01	0.19
Wafi River catchment	A20		0.009	0.0016	0.007	0.016			0.04	39		0.01	0.13
Wafi River catchment	A20		0.007	0.0017	0.003	0.008			0.05	0.01		0.01	0.17
Wafi River catchment	A20		0.001	0.0004	0.003	0.006			0.05	0.01		0.01	219
Wafi River catchment	A20		0.001	0.0017	0.007	0.006			0.05	0.01		0.01	0.01
Wafi River catchment	A20		0.001	0.0017	0.002	0.004			0.01	0.01		0.01	0.19
Wafi River catchment	A20		0.001	0.0001	0.001	0.004			0.03	0.01		0.01	0.18
Wafi River catchment	A20		0.001	0.0018	0.002	0.001			0.04	0.01		0.01	0.02
Wafi River catchment	A20		0.001	0.0016	0.003	0.004			0.03	0.01		0.01	0.08
Wafi River catchment	A20		0.001	0.0016	0.001	0.004			0.04	0.02		0.01	0.17
Wafi River catchment	A20		0.001	0.0001	0.003	0.001			0.04	0.01		0.01	0.07
Wafi River catchment	A20		0.001	0.0017	0.003	0.004			0.04	0.01		0.01	0.14
Wafi River catchment	A20		0.001	0.0012	0.01	0.004			0.04	0.01		0.01	0.11
Wafi River catchment	A20		0.001	0.0016	0.007	0.016			0.05	0.01		0.01	0.17
Wafi River catchment	A20		0.001	0.0017	0.003	0.008			0.05	0.01		0.01	0.15
Wafi River catchment	A20		0.001	0.0004	0.003	0.006			0.02	0.01		0.01	0.18
Wafi River catchment	A20		0.001	0.0017	0.007	0.006			0.04	0.01		0.01	0.18
Wafi River catchment	A20		0.001	0.0012	0.002	0.004			0.03	0.01		0.01	0.05
Wafi River catchment	A20		0.002	0.0016	0.001	0.004			0.03	0.01		0.01	0.15
Wafi River catchment	A20		0.001	1	0.002	0.001			0.04	0.01		0.01	0.13
Wafi River catchment	A20		0.001	0.0001	0.003	0.004			0.03	0.01		0.01	0.13
Wafi River catchment	A20		0.001	0.0015	0.001	0.004			0.03	0.01		0.01	0.14
Wafi River catchment	A20		0.002	0.0015	0.003	0.001			0.04	0.01		0.01	0.12
Wafi River catchment	A20		0.001	0.0003	0.001	0.004			0.03	0.01		0.01	0.13
Wafi River catchment	A20		0.001	0.0011	0.001	0.003			0.03	0.01		0.01	0.15
Wafi River catchment	A20		0.001	0.0014	106	0.004			0.04	0.01		0.01	0.13
Wafi River catchment	A20			0.0008	0.001	96			0.03	0.02			0.13
Wafi River catchment	A20			0.0012	0.003	0.001			0.03	0.006			0.14
Wafi River catchment	A20			0.0008	0.002	0.004			0.054	0.021			0.12
Wafi River catchment	A20			0.0012	0.004	0.004			0.008	0.012			0.13
Wafi River catchment	A20			0.0011	0.003	0.002			0.055	0.015			0.238
Wafi River catchment	A20			0.0015	0.002	0.003			0.053	0.001			0.018
Wafi River catchment	A20				0.003	0.004			0.055	0.016			0.22
Wafi River catchment	A20				0.003	0.003			0.004	0.001			0.203
Wafi River catchment	A20				0.022	0.004			0.05	0.015			0.225
Wafi River catchment	A20				0.007	0.008			0.033	0.017			0.005
Wafi River catchment	A20				0.002	0.005			0.045	0.002			0.197
Wafi River catchment	A20				0.002	0.004			0.052	0.016			0.085
Wafi River catchment	A20					0.004			0.006	0.02			0.205
Wafi River catchment	A20								0.047	0.006			0.207
Wafi River catchment	A20								0.054	0.021			0.011
Wafi River catchment	A20								0.008	0.012			0.186
Wafi River catchment	A20								0.055	0.015			0.238
Wafi River catchment	A20								0.053	0.001			0.018
Wafi River catchment	A20								0.055	0.016			0.22
Wafi River catchment	A20								0.004	0.001			0.203
Wafi River catchment	A20								0.05	0.015			0.225
Wafi River catchment	A20								0.033	0.017			0.005
Wafi River catchment	A20								0.045	0.002			0.197
Wafi River catchment	A20								0.052	0.016			0.085
Wafi River catchment	A20								0.006	0.005			0.205
Wafi River catchment	A20								0.047	0.013			0.207
Wafi River catchment	A20								0.036	39			0.011
Wafi River catchment	A20								0.045	0.001			0.186
Wafi River catchment	A20								0.001	0.013			0.133
Wafi River catchment	A20								0.049	0.014			0.172
Wafi River catchment	A20								0.046	0.003			219
Wafi River catchment	A20								0.008	0.008			0.008
Wafi River catchment	A20								0.025	0.013			0.19
Wafi River catchment	A20								0.044	0.005			0.181
Wafi River catchment	A20								0.026	0.012			0.021
Wafi River catchment	A20								0.038	0.007			0.079
Wafi River catchment	A20								0.042	0.016			0.166
Wafi River catchment	A20								0.044	0.012			0.072
Wafi River catchment	A20								0.037	0.014			0.141
Wafi River catchment	A20								0.046				0.114
Wafi River catchment	A20												0.167
Wafi River catchment	A20												0.15
Wafi River catchment	A20												0.18
Wafi River catchment	A26		0.001	0.0001	0.001	0.006	0.0001		0.009	0.001		0.01	0.055

coffey

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A26		0.001	0.0002	0.001	0.005	0.0001		0.011	48		0.01	0.073
Wafi River catchment	A26		0.001	0.0001	0.01	0.004	0.0001		0.015	0.01		0.01	0.098
Wafi River catchment	A26		0.001	0.0002	77	0.005	0.0001		0.014	0.001		0.01	0.082
Wafi River catchment	A26		0.001	0.0002	0.04	0.003	0.0001		0.007	0.001		0.01	0.034
Wafi River catchment	A26		0.001	0.0001	0.01	0.005	0.0001		0.012	0.001		0.01	0.072
Wafi River catchment	A26		0.001	1	0.01	0.003	0.0001		0.006	0.001		0.01	0.031
Wafi River catchment	A26		0.001	0.001	0.01	0.003	0.0001		0.006	0.001		0.01	0.031
Wafi River catchment	A26		0.001	0.0005	0.001	0.01	0.0001		0.02	0.001		0.01	0.17
Wafi River catchment	A26		0.001	0.0003	0.001	0.01	0.0001		0.02	0.001		0.01	0.13
Wafi River catchment	A26		27	0.0004	0.007	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.1
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.09
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.09
Wafi River catchment	A26		0.001	0.0002	0.003	0.01			0.01	0.001		0.01	0.09
Wafi River catchment	A26		0.001	0.0002	0.001	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.001	0.001	0.01			0.01	0.001		0.01	0.08
Wafi River catchment	A26		0.001	0.0005	0.001	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.05
Wafi River catchment	A26		0.001	0.0004	0.007	0.01			0.01	0.001		0.01	0.08
Wafi River catchment	A26		0.001	0.0003	0.001	52			0.01	0.001		0.01	49
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0003	0.001	0.01			0.01	0.001		0.01	0.08
Wafi River catchment	A26		0.001	0.0002	0.003	0.01			0.04	0.001		0.01	0.07
Wafi River catchment	A26		0.001	0.0002	0.001	0.02			0.01	48		0.01	0.03
Wafi River catchment	A26		0.001	0.0002	0.001	0.01			0.01	0.001		0.01	0.04
Wafi River catchment	A26		0.002	0.0002	0.001	0.01			0.01	0.001		0.01	0.21
Wafi River catchment	A26		0.003	0.0002	0.002	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	1	0.001	0.01			0.01	0.01		0.01	0.04
Wafi River catchment	A26		0.001	0.0002	77	0.01			0.02	0.004		0.01	0.06
Wafi River catchment	A26		0.001	0.0002	0.001	0.01			0.01	0.001		0.01	0.05
Wafi River catchment	A26		0.001	0.0001	0.001	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0001	0.001	0.01			0.01	0.001		0.01	0.07
Wafi River catchment	A26		0.001	0.0001	0.041	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0002	0.004	0.01			0.01	0.001		0.01	0.06
Wafi River catchment	A26		0.001	0.0001	0.001	0.01			0.01	0.004		0.01	0.03
Wafi River catchment	A26			0.0001	0.001	0.01			0.01	0.001		0.01	0.03
Wafi River catchment	A26			0.0001	0.001	0.01			0.01	0.001		0.01	0.07
Wafi River catchment	A26			0.0002	0.001	0.01			0.02			0.01	0.08
Wafi River catchment	A26			0.0003	0.007	0.01			0.01			0.01	0.06
Wafi River catchment	A26			0.0001	0.004	0.01			0.02				0.05
Wafi River catchment	A26			0.0002	0.001	0.01			0.01				0.05
Wafi River catchment	A26				0.001	0.01			0.01				0.08
Wafi River catchment	A26					0.01			0.01				0.06
Wafi River catchment	A26					0.01			0.01				0.06
Wafi River catchment	A26					0.01			0.01				0.04
Wafi River catchment	A26					0.01			0.01				0.07
Wafi River catchment	A26					0.01			0.01				0.06
Wafi River catchment	A26					0.01			0.01				0.03
Wafi River catchment	A26					0.01			0.01				0.07
Wafi River catchment	A26					0.01			0.02				0.08
Wafi River catchment	A26					0.01			0.01				0.06
Wafi River catchment	A26					0.01			0.02				0.05
Wafi River catchment	A26					0.008			0.01				0.05
Wafi River catchment	A26					0.01			0.01				0.08
Wafi River catchment	A26					0.006			0.01				0.06
Wafi River catchment	A26					0.008			0.01				0.06
Wafi River catchment	A26					0.006			0.01				0.04
Wafi River catchment	A26					0.008			0.01				0.07
Wafi River catchment	A26					0.008			0.016				0.06
Wafi River catchment	A26					0.005			0.015				0.06
Wafi River catchment	A26					0.007			0.012				0.168
Wafi River catchment	A26					0.008			0.014				0.128
Wafi River catchment	A26					0.01			0.011				0.062
Wafi River catchment	A26					0.006			0.012				0.1
Wafi River catchment	A26					0.008			0.013				0.086
Wafi River catchment	A26					0.006			0.009				0.085
Wafi River catchment	A26					0.008			0.012				0.087
Wafi River catchment	A26					0.008			0.016				0.055
Wafi River catchment	A26					0.005			0.015				0.082
Wafi River catchment	A26					0.007			0.012				0.168
Wafi River catchment	A26					0.005			0.014				0.128
Wafi River catchment	A26					0.006			0.011				0.062
Wafi River catchment	A26					0.007			0.012				0.1
Wafi River catchment	A26					52			0.013				0.086
Wafi River catchment	A26					0.006			0.009				0.085
Wafi River catchment	A26					0.007			0.012				0.087
Wafi River catchment	A26					0.006			0.009				0.055
Wafi River catchment	A26					0.018			0.009				0.082
Wafi River catchment	A26					0.006			0.012				0.058
Wafi River catchment	A26					0.004			0.011				0.052
Wafi River catchment	A26					0.006			0.013				0.075
Wafi River catchment	A26					0.005			0.012				49
Wafi River catchment	A26					0.005			0.041				0.064
Wafi River catchment	A26					0.007			0.009				0.076
Wafi River catchment	A26					0.006			0.008				0.067
Wafi River catchment	A26					0.006			0.012				0.031
Wafi River catchment	A26					0.004			0.007				0.036
Wafi River catchment	A26								0.009				0.212
Wafi River catchment	A26								0.015				0.058
Wafi River catchment	A26								0.001				0.036
Wafi River catchment	A26								0.012				0.055
Wafi River catchment	A26								0.013				0.051
Wafi River catchment	A26												0.063
Wafi River catchment	A26												0.065
Wafi River catchment	A26												0.06
Wafi River catchment	A30		0.001	0.0001	0.002	0.002	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.01	1	0.004	0.002	0.0001		0.004	10		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.004	100	0.0001		0.004	0.01		0.01	123
Wafi River catchment	A30		0.001	0.0001	52	0.01	0.0001		0.01	0.01		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	0.02
Wafi River catchment	A30		0.001	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001	0.0034		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.0085	0.0185	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.0162	0.0001	0.001	0.001	0.001		0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.0001	0.0046	0.001	0.322	0.0002		0.171	0.659		0.01	0.005
Wafi River catchment	A30		0.0004	0.0022	0.001	0.0207			0.0083	0.008		0.01	0.005
Wafi River catchment	A30		7	0.0001	0.001	0.264			0.147	0.356		0.0128	0.005
Wafi River catchment	A30		0.001	0.0001	0.047	0.0002			0.001	0.019		0.0001	0.005
Wafi River catchment	A30		0.001	0.0001	0.0082	0.001			0.001	0.001		0.0043	0.005
Wafi River catchment	A30		0.001	0.0001	0.0265	0.001			0.001	0.001		0.0002	0.005
Wafi River catchment	A30		0.001	0.0001	0.0008	0.001			0.001	0.001		0.01	2.67

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.0157
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	1.61
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.00005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	1	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	100			0.001	10		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	52	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0004	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.013	0.0001	0.001	0.001			0.001	0.008		0.01	123
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.006	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.01			0.001	0.006		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.001	0.0001	0.007	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A30		0.0029	0.0005	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A30		0.0117	0.0009	0.001	0.001			0.041	0.001		0.01	0.005
Wafi River catchment	A30		0.0105	0.0419	0.001	0.0289			0.44	0.0063		0.01	0.019
Wafi River catchment	A30		0.0399	0.0396	0.001	0.508			0.3856	0.657		0.0001	0.008
Wafi River catchment	A30		0.0017	0.0004	0.001	0.326			0.253	0.274		0.0036	0.005
Wafi River catchment	A30		0.0045	0.0024	0.0048	0.685			0.0049	0.738		0.0039	0.005
Wafi River catchment	A30		0.0082	0.0007	0.0645	0.0025			0.0595	0.0059		0.0158	0.01
Wafi River catchment	A30		0.0094	0.0007	0.0548	0.0319			0.0252	0.0147		0.0107	0.005
Wafi River catchment	A30		0.0085	0.0185	0.1364	0.0274			0.0179	0.0031		0.0001	0.0458
Wafi River catchment	A30		0.0162	0.0001	0.0105	0.0095			0.171	0.0087		0.0051	3.17
Wafi River catchment	A30		0.0001	0.0046	0.0001	0.322			0.0083	0.659		0.0351	2.48
Wafi River catchment	A30		0.0004	0.0022	0.0921	0.0207			0.147	0.008		0.0128	3.18
Wafi River catchment	A30				0.0114	0.264			0.001	0.356		0.0001	0.0927
Wafi River catchment	A30				0.047	0.0002				0.019		0.0043	0.104
Wafi River catchment	A30				0.0082							0.0002	0.118
Wafi River catchment	A30				0.0265								0.129
Wafi River catchment	A30				0.0008								2.67
Wafi River catchment	A30												0.0157
Wafi River catchment	A30												1.61
Wafi River catchment	A30												0.00005
Wafi River catchment	A40		0.002	0.0001	0.01	0.009	0.0001		0.008	0.003		0.01	0.022
Wafi River catchment	A40		0.001	1	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	79	61	0.0001		0.002	10		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.006	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	84
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.001	0.0001	0.001	0.001	0.0028		0.001	0.001		0.01	0.01
Wafi River catchment	A40		0.0068	0.0056	0.001	0.001	0.0019		0.0047	0.001		0.01	0.01
Wafi River catchment	A40		0.0023	0.0001	0.004	0.0093	0.0006		0.0124	0.0056		0.01	0.01
Wafi River catchment	A40		0.0015	0.0001	0.0271	0.0059			0.002	0.0045		0.01	0.01
Wafi River catchment	A40		5	0.0001	0.0011	0.0011			0.002	0.0002		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.006			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.0019	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.002			0.001	0.001		0.0003	0.006
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.0002	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.008
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.015
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.0173
Wafi River catchment	A40		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.0002
Wafi River catchment	A40		0.001	1	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	79	61			0.001	10		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A40		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.008
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.002	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A40		0.001	0.0001	0.001	0.001			0.0001	0.001		0.01	84
Wafi River catchment	A40		0.0046	0.0009	0.001	0.001			0.0055	0.001		0.01	0.005
Wafi River catchment	A40		0.0001	0.0001	0.0001	0.0042			0.18	0.2333		0.01	0.005
Wafi River catchment	A40		0.0001	0.0006	0.0014	0.0008			0.0062	0.003		0.01	0.005
Wafi River catchment	A40		0.0021	0.0001	0.0147	0.0008			0.0031	0.0013		0.01	0.005
Wafi River catchment	A40		0.0001	0.0003	0.0071	0.0019			0.0297	0.0001		0.018	0.005
Wafi River catchment	A40		0.0004	0.0001	0.0153	0.014			0.0039	0.0011		0.0001	0.005
Wafi River catchment	A40		0.0001	0.0001	0.004	0.0034			0.0047	0.0013		0.0018	0.005
Wafi River catchment	A40		0.0068	0.0056	0.0271	0.0029			0.0124	0.0001		0.0114	0.005
Wafi River catchment	A40		0.0023	0.0001	0.0011	0.0093			0.002	0.0056		0.0018	0.005
Wafi River catchment	A40		0.0015	0.0001		0.0059				0.0045		0.006	0.005
Wafi River catchment	A40					0.0011				0.0002		0.0163	0.005
Wafi River catchment	A40											0.0019	0.005
Wafi River catchment	A40											0.0003	0.005
Wafi River catchment	A40											0.0002	0.0031
Wafi River catchment	A40												0.0193
Wafi River catchment	A40												0.0403
Wafi River catchment	A40												0.0116
Wafi River catchment	A40												0.015
Wafi River catchment	A40												0.0173
Wafi River catchment	A40												0.0002
Wafi River catchment	A50		0.001	0.0001	0.001	0.003	0.0001		0.003	0.001		0.01	0.008
Wafi River catchment	A50		0.001	1	0.004	0.001	0.0001		0.001	10		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.01	0.0001		0.01	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.01	52	0.0001		0.001	0.001		0.01	0.02
Wafi River catchment	A50		0.001	0.0001	83	0.07	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.01	0.07	0.0001		0.006	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	71
Wafi River catchment	A50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.005	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.012	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.02

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A50		6	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.16
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.006	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.005			0.001	0.001		0.01	0.16
Wafi River catchment	A50		0.001	0.0001	0.012	0.001			0.001	0.001		0.01	0.01
Wafi River catchment	A50		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.021
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	1	0.001	0.001			0.001	10		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	52			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	83	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.006
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.021
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0002	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A50			0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A50				0.001	0.001						0.01	0.005
Wafi River catchment	A50				0.001	0.001						0.01	0.005
Wafi River catchment	A50				0.001	0.002						0.01	0.005
Wafi River catchment	A50				0.001	0.001						0.01	0.005
Wafi River catchment	A50				0.001								71
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.007
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.016
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A50												0.005
Wafi River catchment	A60		0.006	0.0053	0.063	0.27	0.0001		0.586	0.028		0.01	0.808
Wafi River catchment	A60		0.006	0.0074	0.035	0.142	0.0001		0.24	0.086		0.01	1.6
Wafi River catchment	A60		0.016	0.0081	0.049	0.146	0.0001		0.267	0.065		0.01	1.83
Wafi River catchment	A60		0.006	0.0134	0.056	0.443	0.0001		0.305	0.17		0.01	2.28
Wafi River catchment	A60		0.008	0.0062	0.081	0.392	0.0001		0.734	0.033		0.01	0.989
Wafi River catchment	A60		0.01	0.0091	0.039	0.194	0.0001		0.292	0.085		0.01	1.84
Wafi River catchment	A60		0.01	0.01	0.04	0.26	0.0001		0.28	0.12		0.01	1.74
Wafi River catchment	A60		0.03	0.01	0.05	0.5	0.0001		0.34	0.13		0.01	2.21
Wafi River catchment	A60		0.01	0.01	0.04	0.35	0.0001		0.31	0.12		0.01	2.08
Wafi River catchment	A60		0.01	0.01	0.04	0.55	0.0001		0.27	0.21		0.01	1.82
Wafi River catchment	A60		0.01	0.01	0.03	0.34	0.0056		0.26	0.18		0.01	1.73
Wafi River catchment	A60		0.01	0.01	0.03	0.3	0.0001		0.25	0.18		0.01	1.81
Wafi River catchment	A60		0.01	0.01	0.03	0.21	0.0027		0.24	0.16		0.01	1.65
Wafi River catchment	A60		0.01	0.01	0.04	0.24	0.0001		0.29	0.14		0.01	1.83
Wafi River catchment	A60		0.01	0.02	0.08	0.74	0.001		0.46	1		0.01	2.58
Wafi River catchment	A60		0.01	0.01	0.04	0.27	0.0002		0.31	0.14		0.01	1.78
Wafi River catchment	A60		0.02	0.01	0.03	0.19			0.25	0.12		0.01	1.62
Wafi River catchment	A60		0.01	0.01	0.04	0.34			0.25	0.12		0.0011	1.64
Wafi River catchment	A60		0.01	0.01	0.03	0.25			0.24	0.12		0.0112	1.4
Wafi River catchment	A60		0.01	0.01	0.02	0.23			0.29	0.2		0.0039	1.79
Wafi River catchment	A60		0.01	0.01	0.03	0.25			0.3	0.19		0.0002	367
Wafi River catchment	A60		0.01	2	123	176			0.33	147		0.01	1.86
Wafi River catchment	A60		0.01	0.01	0.03	0.34			0.35	0.18		0.01	1.88
Wafi River catchment	A60		0.01	0.01	0.04	0.26			0.31	0.14		0.01	2.07
Wafi River catchment	A60		0.01	0.01	0.06	0.38			0.26	0.15		0.01	2
Wafi River catchment	A60		0.01	0.01	0.06	0.59			0.26	0.21		0.01	1.37
Wafi River catchment	A60		0.01	0.01	0.02	0.23			0.31	0.14		0.01	1.46
Wafi River catchment	A60		0.01	0.01	0.02	0.25			0.3	0.13		0.01	1.77
Wafi River catchment	A60		0.02	0.01	0.04	0.47			0.29	0.15		0.01	1.82
Wafi River catchment	A60		0.01	0.01	0.04	0.28			0.38	0.12		0.01	1.85
Wafi River catchment	A60		0.01	0.01	0.04	0.26			0.32	0.11		0.01	3.26
Wafi River catchment	A60		0.01	0.02	0.08	0.71			0.42	0.17		0.01	2.59
Wafi River catchment	A60		0.01	0.01	0.05	0.41			0.66	0.14		0.01	2.45
Wafi River catchment	A60		0.015	0.01	0.09	0.77			0.78	0.12		0.01	0.87
Wafi River catchment	A60		0.067	0.01	0.06	0.27			0.63	0.02		0.01	0.93
Wafi River catchment	A60		0.006	0.01	0.06	0.25			0.27	0.02		0.01	0.87
Wafi River catchment	A60		0.002	0.01	0.06	0.25			0.66	0.02		0.01	1.82
Wafi River catchment	A60		0.009	0.01	0.04	0.22			0.78	0.12		0.01	0.87
Wafi River catchment	A60		0.028	0.01	0.06	0.27			0.63	0.02		0.01	0.93
Wafi River catchment	A60		0.009	0.01	0.06	0.25			0.27	0.02		0.01	0.87
Wafi River catchment	A60		0.008	0.01	0.06	0.25			0.238	0.02		0.01	1.82
Wafi River catchment	A60		0.008	0.01	0.04	0.22			0.465	0.12		0.01	1.61
Wafi River catchment	A60		0.008	0.0077	0.04	0.275			0.276	0.092		0.01	2.87
Wafi River catchment	A60		0.009	0.0164	0.106	0.702			0.336	0.08		0.01	1.74
Wafi River catchment	A60		0.008	0.0084	0.038	0.26			0.309	0.12		0.01	2.21
Wafi River catchment	A60		0.0064	0.0119	0.054	0.497			0.271	0.134		0.01	2.08
Wafi River catchment	A60		0.0856	0.0091	0.044	0.348			0.256	0.118		0.01	1.82
Wafi River catchment	A60		0.016	0.0109	0.041	0.55			0.249	0.212		0.01	1.73
Wafi River catchment	A60		0.0069	0.0092	0.034	0.34			0.242	0.181		0.0002	1.81
Wafi River catchment	A60		0.005	0.0088	0.029	0.3			0.293	0.183		0.0011	1.65
Wafi River catchment	A60		200	0.0079	0.028	0.209			0.457	0.157		0.0046	1.83
Wafi River catchment	A60		0.015	0.0082	0.037	0.239			0.246	0.141		0.0109	2.58
Wafi River catchment	A60		0.067	0.0153	0.084	0.744			0.0245	0.995		0.0065	1.62
Wafi River catchment	A60		0.006	0.0076	0.032	0.194			0.18	0.123		0.0001	0.108
Wafi River catchment	A60		0.002	0.015	0.0036	0.0221			0.0015	0.0106		0.0037	2.67
Wafi River catchment	A60		0.009	0.0211	0.0676	0.276			0.32	0.631		0.0644	0.0052
Wafi River catchment	A60		0.028	0.001	0.0018	0.0061			0.238	0.0119		0.0011	0.128
Wafi River catchment	A60		0.009	0.0089	0.029	0.15			0.465	0.029		0.0112	1.5
Wafi River catchment	A60		0.008	0.0077	0.04	0.275			0.276	0.092		0.0039	1.61
Wafi River catchment	A60		0.008	0.0164	0.106	0.702			0.336	0.08		0.0002	2.87
Wafi River catchment	A60		0.008	0.0084	0.038	0.26			0.309	0.12			1.74
Wafi River catchment	A60		0.009	0.0119	0.054	0.497			0.271	0.134			2.21
Wafi River catchment	A60		0.006	0.0091	0.044	0.348			0.256	0.118			2.08
Wafi River catchment	A60		0.008	0.0109	0.041	0.55			0.249	0.212			1.82
Wafi River catchment	A60		0.007	0.0092	0.034	0.34			0.242	0.181			1.73
Wafi River catchment	A60		0.02	0.0088	0.029	0.3			0.293	0.183			1.81
Wafi River catchment	A60		0.01	0.0079	0.028	0.209			0.457	0.157			1.65
Wafi River catchment	A60		0.006	0.0082	0.037	0.239			0.311	0.141			1.83
Wafi River catchment	A60		0.002	0.0153	0.084	0.744			0.246	0.995			2.58

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	A60		0.01	0.009	0.039	0.265			0.25	0.138			1.78
Wafi River catchment	A60		0.007	0.0076	0.032	0.194			0.238	0.123			1.62
Wafi River catchment	A60		0.006	0.0085	0.038	0.343			0.288	0.123			1.64
Wafi River catchment	A60		0.006	0.0079	0.028	0.247			0.3	0.121			1.4
Wafi River catchment	A60		0.011	0.0082	0.02	0.228			0.326	0.204			1.79
Wafi River catchment	A60		0.007	0.009	0.03	0.252			0.351	0.194			367
Wafi River catchment	A60		0.006	2	123	176			0.309	147			1.86
Wafi River catchment	A60		0.007	0.0087	0.031	0.34			0.256	0.177			1.88
Wafi River catchment	A60		0.005	0.0086	0.041	0.256			0.263	0.14			2.07
Wafi River catchment	A60		0.0031	0.0103	0.056	0.384			0.306	0.15			2
Wafi River catchment	A60		0.0001	0.011	0.059	0.588			0.299	0.207			1.37
Wafi River catchment	A60		0.002	0.0074	0.019	0.225			0.286	0.138			1.46
Wafi River catchment	A60		0.0083	0.0078	0.024	0.246			0.322	0.13			1.77
Wafi River catchment	A60		0.0143	0.0102	0.042	0.465			0.224	0.147			1.82
Wafi River catchment	A60		0.0079	0.0095	0.037	0.276			0.0395	0.122			1.85
Wafi River catchment	A60		0.0148	0.009	0.037	0.255			0.0308	0.111			2.59
Wafi River catchment	A60		0.0064	0.0139	0.052	0.412			0.0301	0.138			3.13
Wafi River catchment	A60		0.0856	0.0148	0.439	0.458			0.0051	0.241			0.087
Wafi River catchment	A60		0.016	0.0007	0.0067	0.0113			0.0973	0.0024			0.143
Wafi River catchment	A60		0.0069	0.002	0.0301	0.0172			0.179	0.0059			0.108
Wafi River catchment	A60			0.0015	0.0324	0.0141			0.217	0.0101			2.09
Wafi River catchment	A60			0.0141	0.0505	0.0041			0.0245	0.0595			1.89
Wafi River catchment	A60			0.0135	0.0324	0.24			0.18	0.531			2.14
Wafi River catchment	A60			0.0102	0.0305	0.224			0.0015	0.365			0.108
Wafi River catchment	A60			0.0109	0.0036	0.217			0.32	0.215			2.67
Wafi River catchment	A60			0.015	0.0676	0.0221				0.0106			0.0052
Wafi River catchment	A60			0.0211	0.0018	0.276				0.631			0.128
Wafi River catchment	A60			0.001	0.029	0.0061				0.0119			
Wafi River catchment	A60			0.0089		0.15				0.029			
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.012
Wafi River catchment	A80		0.001	1	0.01	91	0.0001		0.001	0.01		0.01	0.012
Wafi River catchment	A80		0.001	0.0001	80	0.001	0.0001		0.001	13		0.01	0.01
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	139
Wafi River catchment	A80		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.007
Wafi River catchment	A80		0.001	0.0001	0.009	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A80		7	0.0001	0.001	0.001			0.001	0.005		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.011
Wafi River catchment	A80		0.001	0.0001	0.001	0.002			0.001	0.001		0.01	0.007
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A80		0.001	0.0001	0.009	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.005		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	1	0.001	91			0.001	0.001		0.01	0.011
Wafi River catchment	A80		0.001	0.0001	80	0.001			0.001	13		0.01	0.007
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.003	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	139
Wafi River catchment	A80		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A80		0.001	0.0001	0.002	0.001				0.001		0.01	0.005
Wafi River catchment	A80			0.0001	0.001	0.001				0.001		0.01	0.005
Wafi River catchment	A80				0.001					0.001			0.005
Wafi River catchment	A80												0.005
Wafi River catchment	A80												0.005
Wafi River catchment	A80												0.005
Wafi River catchment	A80												0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.002		0.01	0.005
Wafi River catchment	A90		0.001	1	50	65	0.0001		0.26	0.001		0.01	0.01
Wafi River catchment	A90		0.001	0.0001	0.01	0.12	0.0001		0.001	10		0.01	83
Wafi River catchment	A90		0.001	0.0001	0.001	0.01	0.0001		0.001	0.02		0.01	0.01
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.3
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.007
Wafi River catchment	A90		0.0064	0.0001	0.001	0.001	0.0023		0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.0041	0.0034	0.001	0.001	0.0021		0.0055	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.0451	0.001	0.0002		0.0138	0.001		0.0001	0.005
Wafi River catchment	A90		5	0.0001	0.0326	0.0099			0.001	0.0015		0.0011	0.005
Wafi River catchment	A90		0.001	0.0001	0.0012	0.007			0.001	0.0124		0.0002	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.0004			0.001	0.0014		0.01	0.019
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.0291
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.00005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.007
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	1	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	50	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	65			0.001	10		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.001	0.001		0.01	83
Wafi River catchment	A90		0.001	0.0001	0.001	0.001			0.002	0.001		0.01	0.005
Wafi River catchment	A90		0.004	0.0001	0.001	0.001			0.258	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0022	0.003	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.001	0.0001	0.006	0.001			0.001	0.001		0.01	0.005
Wafi River catchment	A90		0.0001	0.0001	0.001	0.12			0.0013	0.02		0.01	0.005
Wafi River catchment	A90		0.0017	0.00005	0.001	0.008			0.0001	0.001		0.0005	0.005
Wafi River catchment	A90		0.0014	0.0005	0.0006	0.001			0.0079	0.001		0.0032	0.303
Wafi River catchment	A90		0.0001	0.0003	0.0018	0.0007			0.0005	0.0032		0.0098	0.005
Wafi River catchment	A90		0.0001	0.0015	0.0001	0.0019			0.0033	0.0013		0.0001	0.005
Wafi River catchment	A90		0.0004	0.0001	0.0141	0.0001			0.006	0.0001		0.0024	0.0001
Wafi River catchment	A90		0.0001	0.0001	0.0065	0.0023			0.0096	0.0001		0.0052	0.00003
Wafi River catchment	A90		0.0064	0.0047	0.0126	0.0026			0.0055	0.0036		0.0001	0.0209
Wafi River catchment	A90		0.0041	0.0034	0.0451	0.0057			0.0138	0.0015		0.0001	0.0193
Wafi River catchment	A90		0.001	0.0001	0.0326	0.0207			0.001	0.0079		0.0011	0.09
Wafi River catchment	A90			0.0001	0.0012	0.0099				0.0015		0.0002	0.0142
Wafi River catchment	A90					0.007				0.0124			0.019
Wafi River catchment	A90					0.0004				0.0014			0.0291
Wafi River catchment	A90												0.00005
Wafi River catchment	G1-3		0.0018	0.0058	0.0013	0.41			0.0001	0.0493		0.0206	0.023
Wafi River catchment	G1-3		0.005	0.0005	0.0307	0.0076			0.0302	0.0128		0.0029	0.0002
Wafi River catchment	G1-3		0.0009	0.00005	0.0009	0.0027			0.0057	0.0066		0.0011	0.0176
Wafi River catchment	G1-3		0.0023	0.00005	0.0006	0.0015			0.0026	0.0025		0.0007	0.0083
Wafi River catchment	G1-3		0.001	0.00005	0.007	0.0025			0.0019	0.0001		0.0005	0.0223

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Wafi River catchment	G1-3		0.0006	0.00005	0.0023	0.0005			0.001	0.0001		0.0039	0.0177
Wafi River catchment	G1-3		0.0001	0.0003	0.0016	0.0033			0.0027	0.003		0.0001	0.0062
Wafi River catchment	G1-3		0.0012	0.00005	0.0005	0.0023			0.0024	0.0013		0.0027	0.0963
Wafi River catchment	G1-3		0.0029	0.00005	0.0149	0.0001			0.0005	0.0083		0.0001	0.0142
Wafi River catchment	G1-3		0.002	0.0006	0.0208	0.0055			0.0005	0.0017		0.0001	0.03
Wafi River catchment	G1-3		0.0032	0.0002	0.0311	0.0093			0.0072	0.0019		0.0004	0.0209
Wafi River catchment	G1-3		0.0001	0.0003	0.0106	0.005			0.0044	0.0015		0.0221	0.021
Wafi River catchment	G1-3		0.0062	0.0008	0.0138	0.0065			0.0064	0.0004		0.003	0.07
Wafi River catchment	G1-3		0.0019	0.00005	0.0202	0.0104			0.011	0.0022		0.0055	0.0239
Wafi River catchment	G1-3		0.0027	0.0013	0.0129	0.0124			0.0042	0.0093		0.0081	0.0752
Wafi River catchment	G1-3		0.0001	0.00005	0.0023	0.004			0.0055	0.0039		0.0007	0.012
Wafi River catchment	G1-3		0.0099	0.0004	0.0067	0.0096			0.0015	0.0011		0.0371	0.0141
Wafi River catchment	G1-3		0.0088	0.0034	0.0989	0.0103			0.0063	0.0025		0.0029	0.014
Wafi River catchment	G1-3		0.013	0.00005	0.0369	0.0076			0.063	0.0186		0.0246	0.13
Wafi River catchment	G1-3		0.0123	0.0002	0.0013	0.0604			0.0167	0.0418		0.0135	0.0356
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0002	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C40		0.001	0.0001	0.003	0.004	0.0001		0.003	0.001		0.01	0.005
Wampit River catchment	C40		0.0073	0.0217	0.0032	0.0152	0.0016		0.0023	0.0715		0.0083	0.017
Wampit River catchment	C40		0.0037	0.0001	0.0111	0.024	0.0001		0.0126	0.0044		0.0006	0.0151
Wampit River catchment	C40		0.007	0.00005	0.0343	0.0227	0.0001		0.0147	0.0079		0.0212	0.0272
Wampit River catchment	C40												0.0362
Wampit River catchment	C50		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C50		0.001	0.0001	0.002	0.004	0.0001		0.002	0.001		0.01	0.005
Wampit River catchment	C50		0.002	0.0001	0.007	0.007	0.0001		0.005	0.002		0.01	0.016
Wampit River catchment	C50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.006
Wampit River catchment	C50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.036
Wampit River catchment	C50		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C50		0.001	0.0001	0.002	0.001	0.0001		0.001	0.001		0.01	0.008
Wampit River catchment	C60		0.001	0.0001	0.003	0.004	0.0001		0.003	0.002		0.01	0.006
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Wampit River catchment	C60		0.001	0.0002	0.001	0.001	0.0001		0.001	0.001		0.01	0.017
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.008
Wampit River catchment	C60		0.001	0.0004	0.001	0.001	0.0001		0.001	0.001		0.01	0.011
Wampit River catchment	C60		0.001	0.0001	0.006	0.002	0.0001		0.004	0.001		0.01	0.005
Wampit River catchment	C60		0.001	0.0001	0.03	0.001	0.0001		0.002	0.001		0.01	0.017
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.008
Wampit River catchment	C60		0.001	0.0001	0.001	0.003	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C60		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C60		0.001	0.0022	0.001	0.001	0.0027		0.001	0.001		0.0016	0.005
Wampit River catchment	C60		0.0081	0.00005	0.0048	0.0105	0.0001		0.003	0.0026		0.0001	0.005
Wampit River catchment	C60		0.0167	0.001	0.0088	0.0211	0.0002		0.0005	0.0016		0.0002	0.048
Wampit River catchment	C60		0.0035	0.8	0.0028	0.0013	0.0002		0.001	0.011		0.013	0.0202
Wampit River catchment	C60		2.6	0.0012	0.0005	0.0035	0.0007		0.001	0.0005		0.0003	0.0141
Wampit River catchment	C60		0.0032	0.0003	0.0011	0.0026	0.0006		0.0005	0.0027		0.0122	0.00005
Wampit River catchment	C60		0.0037		0.0316	0.0037			0.0005	0.0051			0.00005
Wampit River catchment	C60												0.0185
Wampit River catchment	C60												0.0191
Wampit River catchment	C70		0.001	0.0001	0.008	0.002	0.0001		0.006	0.003		0.01	0.02
Wampit River catchment	C70		0.003	0.0001	0.001	0.01	0.0001		0.001	0.001		0.01	0.008
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.002	0.0003	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.008
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Wampit River catchment	C70		0.001		0.001	0.001			0.001	0.001			0.005
Wampit River catchment	C70		0.001			0.001							
Wampit River catchment	C70		0.001										
Wafi River catchment	G1-3		0.0124	0.0004	0.0002	0.0068			0.001	0.0069		0.0264	0.0003
Wafi River catchment	G1-3		0.0002	0.0009		0.0007			0.001	0.0052		0.048	0.00005
Wafi River catchment	G1-3		0.0011	0.035		0.002				0.0007		0.0012	
Watut River catchment	B20		0.006	0.0001	0.006	0.008	0.0001		0.006	0.003		0.01	0.009
Watut River catchment	B20		0.03	0.0001	0.023	0.034	0.0001		0.015	0.029		0.01	0.078
Watut River catchment	B20		0.007	0.0012	0.025	0.001	0.0001		0.019	0.005		0.01	0.008
Watut River catchment	B20		0.015	0.0002	0.133	0.037	0.0001		0.123	0.017		0.01	0.066
Watut River catchment	B20		0.103	0.0004	0.04	0.209	0.0001		0.032	0.152		0.01	0.428
Watut River catchment	B20		0.025	0.0001	0.08	0.047	0.0001		0.079	0.02		0.01	0.086
Watut River catchment	B20		0.025	0.0001	0.005	0.126	0.0001		0.004	0.057		0.01	0.188
Watut River catchment	B20		0.008	0.0001	0.004	0.008	0.0001		0.003	0.004		0.01	0.013
Watut River catchment	B20		0.01	1	0.006	0.006	0.0001		0.005	0.004		0.01	0.01
Watut River catchment	B20		0.01	0.0001	0.009	0.008	0.0001		0.007	0.004		0.01	0.016
Watut River catchment	B20		0.02	0.0004	0.006	0.014	0.0001		0.005	0.015		0.01	0.036
Watut River catchment	B20		0.01	0.0001	0.002	0.008	0.0001		0.002	0.004		0.01	0.016
Watut River catchment	B20		0.005	0.0001	0.005	0.004	0.0001		0.004	0.002		0.01	0.015
Watut River catchment	B20		0.011	0.0001	0.028	0.008	0.002		0.025	0.004		0.01	0.013
Watut River catchment	B20		0.023	0.0001	0.002	0.042	0.0002		0.002	0.02		0.01	0.074
Watut River catchment	B20		0.005	0.0001	0.02	0.004			0.03	0.002		0.01	0.015
Watut River catchment	B20		0.03	0.0001	0.02	0.05			0.02	0.02		0.01	0.07
Watut River catchment	B20		0.01	0.0001	0.02	0.01			0.02	0.02		0.01	0.01
Watut River catchment	B20		0.04	0.0001	0.01	0.04			0.01	0.01		0.01	0.06
Watut River catchment	B20		0.01	0.0001	0.01	0.03			0.01	0.01		0.0009	0.04
Watut River catchment	B20		0.01	0.001	40	0.01			0.02	0.01		0.0002	0.01
Watut River catchment	B20		0.01		0.02	0.01			0.03	0.04			0.01
Watut River catchment	B20		0.01		0.01	0.01			0.03	17			0.01
Watut River catchment	B20		0.01		0.04	0.01			0.07	0.01			0.01
Watut River catchment	B20		0.01		0.04	0.02			0.01	0.02			0.02
Watut River catchment	B20		0.01		0.08	0.08			0.04	0.02			0.03
Watut River catchment	B20		0.01		0.01	62			0.01	0.04			91
Watut River catchment	B20		0.09		0.04	0.03			0.01	0.03			0.04
Watut River catchment	B20		0.01		0.01	0.01			0.02	0.01			0.01
Watut River catchment	B20		0.01		0.01	0.04			0.01	0.01			0.01
Watut River catchment	B20		0.01		0.01	0.04			0.01	0.01			0.07
Watut River catchment	B20		0.01		0.01	0.1			0.01	0.01			0.06
Watut River catchment	B20		0.01		0.01	0.01			0.01	0.01			0.01
Watut River catchment	B20		0.02		0.01	0.08			0.005	0.01			0.13
Watut River catchment	B20		0.01		0.01	0.02			0.027	0.01			0.02
Watut River catchment	B20		0.02		0.01	0.02			0.003	0.01			0.01
Watut River catchment	B20		0.02		0.003	0.02			0.02	0.006			0.1
Watut River catchment	B20		0.01		0.015	0.02			0.023	0.016			0.04
Watut River catchment	B20		0.03		0.004	0.01			0.001	0.002			0.03
Watut River catchment	B20		0.02		0.024	0.01			0.002	0.021			0.04
Watut River catchment	B20		0.01		0.023	0.01			0.002	0.007			0.03

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Watut River catchment	B20		0.01		0.002	0.01			0.001	0.003			0.02
Watut River catchment	B20		0.01		0.002	0.014			0.002	0.003			0.01
Watut River catchment	B20		0.01		0.003	0.052			0.023	0.003			0.02
Watut River catchment	B20		0.01		0.001	0.007			0.018	0.001			0.02
Watut River catchment	B20		0.01		0.002	0.04				0.001			0.01
Watut River catchment	B20		0.01		0.0449	0.026				0.0203			0.02
Watut River catchment	B20		0.007		0.0094	0.003				0.0029			0.017
Watut River catchment	B20		0.025			0.005							0.074
Watut River catchment	B20		0.009			0.005							0.01
Watut River catchment	B20		0.036			0.006							0.06
Watut River catchment	B20		0.01			0.003							0.039
Watut River catchment	B20		0.009			0.0498							0.007
Watut River catchment	B20		0.008			0.0081							0.009
Watut River catchment	B20		0.009										0.013
Watut River catchment	B20		0.005										0.005
Watut River catchment	B20		0.006										0.005
Watut River catchment	B20		0.0085										0.0982
Watut River catchment	B20		0.0075										0.0013
Watut River catchment	B30		0.008	0.0002	0.005	0.007	0.0001		0.005	0.004		0.01	0.012
Watut River catchment	B30		0.008	0.0001	0.003	0.004	0.0001		0.003	0.003		0.01	0.008
Watut River catchment	B30		0.01	0.0001	0.007	0.008	0.0001		0.007	0.004		0.01	0.014
Watut River catchment	B30		0.027	0.0001	0.026	0.034	0.0001		0.02	0.023		0.01	0.086
Watut River catchment	B30		0.01	1	0.007	0.008	0.0001		0.007	0.004		0.01	0.014
Watut River catchment	B30		0.004	0.0002	0.002	0.004	0.0001		0.002	0.002		0.01	0.006
Watut River catchment	B30		0.014	0.0001	0.006	0.009	0.0001		0.005	0.007		0.01	0.018
Watut River catchment	B30		0.008	0.0004	0.005	0.011	0.0001		0.004	0.004		0.01	0.014
Watut River catchment	B30		0.004	0.0002	0.002	0.004	0.0001		0.002	0.002		0.01	0.006
Watut River catchment	B30		0.02	0.0001	0.01	0.02	0.0001		0.01	0.01		0.01	0.07
Watut River catchment	B30		0.01	0.0003	0.03	0.01	0.0001		0.02	0.03		0.01	0.01
Watut River catchment	B30		0.06	0.0001	0.02	0.05	0.0001		0.02	0.01		0.01	0.09
Watut River catchment	B30		0.01	0.0001	0.01	0.02	0.0001		0.01	0.01		0.01	0.03
Watut River catchment	B30		0.01	0.0001	0.01	0.01	0.0001		0.01	0.02		0.01	0.01
Watut River catchment	B30		0.01	0.0001	28	0.01	0.0001		0.01	20		0.01	0.02
Watut River catchment	B30		0.01	0.0001	0.01	0.01	0.0023		0.03	0.01		0.01	0.01
Watut River catchment	B30		0.01	0.0001	0.04	0.01	0.0001		0.02	0.02		0.01	0.01
Watut River catchment	B30		0.01	0.00005	0.02	0.03	0.0006		0.06	0.01		0.01	0.02
Watut River catchment	B30		0.01	0.0001	0.07	53	0.0002		0.01	0.04		0.01	0.04
Watut River catchment	B30		0.02	0.0008	0.02	0.02	0.0002		0.01	0.01		0.01	91
Watut River catchment	B30		0.01	0.026	0.01	0.04			0.01	0.01		0.0029	0.03
Watut River catchment	B30		0.01	0.0002	0.01	0.02			0.05	0.01		0.0001	0.01
Watut River catchment	B30		0.02		0.01	0.09			0.056	0.01		0.0001	0.07
Watut River catchment	B30		0.01		0.06	0.01			0.004	0.05		0.0002	0.03
Watut River catchment	B30		0.02		0.056	0.01			0.008	0.025		0.0003	0.12
Watut River catchment	B30		0.01		0.002	0.03			0.01	0.003			0.01
Watut River catchment	B30		0.01		0.01	0.02			0.002	0.006			0.01
Watut River catchment	B30		0.02		0.011	0.02			0.021	0.013			0.02
Watut River catchment	B30		0.01		0.003	0.01			0.017	0.001			0.03
Watut River catchment	B30		0.02		0.026	0.09			0.001	0.031			0.04
Watut River catchment	B30		0.05		0.02	0.074			0.002	0.006			0.04
Watut River catchment	B30		0.026		0.001	0.009			0.001	0.002			0.02
Watut River catchment	B30		0.005		0.002	0.015			0.001	0.004			0.17
Watut River catchment	B30		0.008		0.002	0.019			0.003	0.002			0.114
Watut River catchment	B30		0.021		0.002	0.005			0.0036	0.001			0.01
Watut River catchment	B30		0.006		0.003	0.054			0.0042	0.001			0.018
Watut River catchment	B30		0.055		0.0007	0.019			0.0005	0.0065			0.07
Watut River catchment	B30		0.009		0.0149	0.002			0.012	0.0021			0.011
Watut River catchment	B30		0.005		0.0027	0.005			0.022	0.007			0.09
Watut River catchment	B30		0.007		0.0073	0.003				0.0098			0.028
Watut River catchment	B30		0.006		0.0093	0.008				0.0098			0.005
Watut River catchment	B30		0.005			0.004							0.007
Watut River catchment	B30		0.004			0.0053							0.015
Watut River catchment	B30		0.0694			0.0336							0.007
Watut River catchment	B30		0.0041			0.0035							0.005
Watut River catchment	B30		0.005			0.005							0.152
Watut River catchment	B30		0.012			0.017							0.034
Watut River catchment	B30		0.021										0.0097
Watut River catchment	B30												0.0022
Watut River catchment	B30												0.0033
Watut River catchment	B40		0.014	0.0019	0.011	0.024	0.0001		0.012	0.015		0.01	0.033
Watut River catchment	B40		0.009	0.0001	0.004	0.007	0.0001		0.004	0.004		0.01	0.01
Watut River catchment	B40		0.011	0.0003	0.012	0.016	0.0001		0.011	0.01		0.01	0.03
Watut River catchment	B40		0.008	0.0001	0.005	0.006	0.0001		0.003	0.004		0.01	0.014
Watut River catchment	B40		0.012	0.0001	0.008	0.011	0.0001		0.005	0.009		0.01	0.026
Watut River catchment	B40		0.005	0.0001	0.004	0.001	0.0001		0.003	0.013		0.01	0.037
Watut River catchment	B40		0.016	1	0.008	0.009	0.0001		0.009	0.008		0.01	0.027
Watut River catchment	B40		0.01	0.0006	0.005	0.014	0.0001		0.003	0.014		0.01	0.03
Watut River catchment	B40		0.014	0.0001	0.008	0.007	0.0001		0.001	0.008		0.01	0.02
Watut River catchment	B40		0.01	0.0001	0.006	0.012	0.0001		0.004	0.006		0.01	0.02
Watut River catchment	B40		0.007	0.0001	0.148	0.009	0.0001		0.118	0.215		0.01	0.53
Watut River catchment	B40		0.148	0.0001	0.022	0.227	0.0001		0.019	0.017		0.01	0.06
Watut River catchment	B40		0.021	0.0004	0.05	0.029	0.0001		0.046	0.047		0.01	0.129
Watut River catchment	B40		0.032	0.0001	0.012	0.082	0.0001		0.016	0.016		0.01	0.028
Watut River catchment	B40		0.015	0.0001	0.003	0.014	0.0001		0.003	0.002		0.01	0.008
Watut River catchment	B40		0.007	0.0001	0.012	0.004			0.013	0.006		0.01	0.026
Watut River catchment	B40		0.011	0.0001	0.016	0.017			0.01	0.01		0.01	0.037
Watut River catchment	B40		0.014	0.0001	0.012	0.016			0.013	0.006		0.01	0.026
Watut River catchment	B40		0.011	0.0001	0.001	0.017			0.001	0.001		0.01	0.012
Watut River catchment	B40		0.003		0.004	0.002			0.003	0.006		0.01	0.054
Watut River catchment	B40		0.013		0.018	0.006			0.016	0.015		0.01	0.005
Watut River catchment	B40		0.017		0.001	0.026			0.001	0.001			0.05
Watut River catchment	B40		0.003		0.03	0.002			0.02	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.02			0.01	0.05			0.11
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.02
Watut River catchment	B40		0.06		0.01	0.06			0.01	0.02			0.05
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.02
Watut River catchment	B40		0.02		28	0.02			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.01			0.05	24			0.01
Watut River catchment	B40		0.01		0.04	0.02			0.1	0.02			0.03
Watut River catchment	B40		0.01		0.11	0.02			0.01	0.01			0.03
Watut River catchment	B40		0.02		0.01	54			0.01	0.04			98
Watut River catchment	B40		0.02		0.01	0.03			0.02	0.07			0.05
Watut River catchment	B40		0.03		0.02	0.01			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.02			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.08			0.04	0.01			0.03
Watut River catchment	B40		0.01		0.01	0.17			0.01	0.02			0.12
Watut River catchment	B40		0.02		0.03	0.02			0.01	0.01			0.25
Watut River catchment	B40		0.03		0.01	0.01			0.01	0.01			0.03
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.02
Watut River catchment	B40		0.01		0.01	0.04			0.01	0.06			0.01
Watut River catchment	B40		0.01		0.01	0.02			0.01	0.01			0.06
Watut River catchment	B40		0.03		0.01	0.02			0.01	0.02			0.04
Watut River catchment	B40		0.02		0.01	0.01			0.01	0.01			0.04
Watut River catchment	B40		0.02		0.01	0.07			0.01	0.01			0.02
Watut River catchment	B40		0.02		0.01	0.01			0.01	0.02			0.12
Watut River catchment	B40		0.04		0.01	0.02			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.02			0.01	0.02			0.03
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.06

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Watut River catchment	B40		0.02		0.01	0.01			0.01	0.01			0.03
Watut River catchment	B40		0.01		0.01	0.02			0.01	0.02			0.01
Watut River catchment	B40		0.01		0.01	0.01			0.01	0.01			0.01
Watut River catchment	B40		0.01		0.01	0.02			0.057	0.01			0.04
Watut River catchment	B40		0.01		0.01	0.03			0.006	0.02			0.02
Watut River catchment	B40		0.01		0.01	0.01			0.011	0.01			0.05
Watut River catchment	B40		0.01		0.01	0.01			0.003	0.02			0.04
Watut River catchment	B40		0.01		0.063	0.01			0.003	0.01			0.01
Watut River catchment	B40		0.01		0.003	0.02			0.022	0.048			0.04
Watut River catchment	B40		0.01		0.012	0.02			0.008	0.005			0.03
Watut River catchment	B40		0.02		0.001	0.01			0.014	0.01			0.06
Watut River catchment	B40		0.01		0.003	0.01			0.004	0.012			0.03
Watut River catchment	B40		0.01		0.026	0.02			0.001	0.002			0.01
Watut River catchment	B40		0.01		0.009	0.01			0.001	0.046			0.01
Watut River catchment	B40		0.01		0.014	0.02			0.002	0.007			0.04
Watut River catchment	B40		0.01		0.004	0.03				0.015			0.02
Watut River catchment	B40		0.01		0.001	0.01				0.006			0.05
Watut River catchment	B40		0.01		0.001	0.01				0.003			0.04
Watut River catchment	B40		0.01		0.002	0.102				0.001			0.01
Watut River catchment	B40		0.081			0.008				0.001			0.04
Watut River catchment	B40		0.005			0.021							0.202
Watut River catchment	B40		0.012			0.024							0.016
Watut River catchment	B40		0.012			0.005							0.026
Watut River catchment	B40		0.007			0.059							0.048
Watut River catchment	B40		0.06			0.014							0.007
Watut River catchment	B40		0.01			0.022							0.109
Watut River catchment	B40		0.017			0.012							0.023
Watut River catchment	B40		0.013			0.003							0.046
Watut River catchment	B40		0.005			0.008							0.015
Watut River catchment	B40		0.004			0.004							0.008
Watut River catchment	B40		0.005										0.012
Watut River catchment	B40												0.005
Watut River catchment	B50		0.014	0.0002	0.014	0.029	0.0001		0.016	0.016		0.01	0.04
Watut River catchment	B50		0.01	0.0022	0.006	0.009	0.0001		0.005	0.005		0.01	0.014
Watut River catchment	B50		0.011	0.0002	0.011	0.015	0.0001		0.013	0.01		0.01	0.028
Watut River catchment	B50		0.005	0.0003	0.002	0.003	0.0001		0.001	0.002		0.01	0.008
Watut River catchment	B50		0.013	0.0001	0.008	0.012	0.0001		0.005	0.009		0.01	0.027
Watut River catchment	B50		0.005	0.0001	0.015	0.002	0.0001		0.01	0.032		0.01	0.085
Watut River catchment	B50		0.036	0.1	0.002	0.029	0.0001		0.003	0.003		0.01	0.01
Watut River catchment	B50		0.006	0.0001	0.017	0.002	0.0001		0.011	0.018		0.01	0.011
Watut River catchment	B50		0.015	1	0.013	0.029	0.0001		0.01	0.012		0.01	0.051
Watut River catchment	B50		0.011	0.0006	0.151	0.019	0.0001		0.128	0.219		0.01	0.042
Watut River catchment	B50		0.15	0.0001	0.033	0.239	0.0001		0.028	0.024		0.01	0.564
Watut River catchment	B50		0.026	0.0001	0.05	0.044	0.0088		0.048	0.048		0.01	0.09
Watut River catchment	B50		0.032	0.0001	0.013	0.083	0.0001		0.017	0.019		0.01	0.136
Watut River catchment	B50		0.016	0.0001	0.003	0.016	0.0001		0.004	0.003		0.01	0.034
Watut River catchment	B50		0.007	0.0004	0.011	0.004	0.0001		0.01	0.004		0.01	0.01
Watut River catchment	B50		0.01	0.0001	0.015	0.012			0.012	0.013		0.01	0.02
Watut River catchment	B50		0.017	0.0001	0.011	0.019			0.01	0.004		0.01	0.046
Watut River catchment	B50		0.01	0.0001	0.003	0.012			0.001	0.001		0.01	0.02
Watut River catchment	B50		0.004	0.0001	0.01	0.002			0.003	0.005		0.01	0.011
Watut River catchment	B50		0.012	0.0001	0.001	0.005			0.009	0.009		0.01	0.03
Watut River catchment	B50		0.012	0.0001	0.01	0.016			0.001	0.001		0.01	0.005
Watut River catchment	B50		0.004	0.0006	0.02	0.002			0.01	0.02		0.01	0.04
Watut River catchment	B50		0.03	0.0001	0.01	0.02			0.02	0.04		0.01	0.02
Watut River catchment	B50		0.01	0.0001	0.01	0.01			0.01	0.01		0.01	0.09
Watut River catchment	B50		0.05	0.0001	0.01	0.05			0.01	0.01		0.01	0.02
Watut River catchment	B50		0.01	0.0001	49	0.01			0.01	0.01		0.01	0.01
Watut River catchment	B50		0.01	0.0004	0.03	0.03			0.01	0.01		0.01	0.02
Watut River catchment	B50		0.01	0.0001	0.07	0.01			0.03	0.01		0.01	0.01
Watut River catchment	B50		0.01	0.0001	0.15	0.01			0.06	0.01		0.01	0.01
Watut River catchment	B50		0.01	0.0001	0.01	0.02			0.14	24		0.01	0.01
Watut River catchment	B50		0.01	0.0001	0.02	0.02			0.01	0.04		0.01	0.04
Watut River catchment	B50		0.02	0.0001	0.02	0.01			0.01	0.05		0.01	0.03
Watut River catchment	B50		0.01	0.0001	0.01	66			0.02	0.08		0.01	0.02
Watut River catchment	B50		0.01	0.0001	0.01	0.06			0.01	0.01		0.01	111
Watut River catchment	B50		0.05	0.0001	0.01	0.01			0.01	0.01		0.01	0.11
Watut River catchment	B50		0.01	0.0001	0.13	0.01			0.14	0.01		0.01	0.02
Watut River catchment	B50		0.01	1	0.01	0.01			0.01	0.02		0.01	0.01
Watut River catchment	B50		0.01	0.0003	0.01	0.11			0.01	0.01		0.01	0.01
Watut River catchment	B50		0.02	0.0002	0.05	0.21			0.06	0.01		0.01	0.18
Watut River catchment	B50		0.03	0.0001	0.01	0.02			0.01	0.01		0.01	0.33
Watut River catchment	B50		0.01	0.0001	0.01	0.02			0.01	0.17		0.01	0.02
Watut River catchment	B50		0.02	0.0002	0.04	0.01			0.03	0.01		0.01	0.05
Watut River catchment	B50		0.01	0.0007	0.01	0.03			0.01	0.01		0.01	0.02
Watut River catchment	B50		0.03	0.0001	0.01	0.01			0.01	0.01		0.01	0.06
Watut River catchment	B50		0.02	0.0001	0.01	0.01			0.01	0.01		0.01	0.03
Watut River catchment	B50		0.01	0.0001	0.01	0.01			0.01	0.01		0.01	0.03
Watut River catchment	B50		0.01	0.0001	0.05	0.27			0.06	0.07		0.01	0.02
Watut River catchment	B50		0.09	0.0001	0.01	0.01			0.01	0.01		0.01	0.51
Watut River catchment	B50		0.01	0.0001	0.01	0.01			0.01	0.01		0.01	0.01
Watut River catchment	B50		0.01	0.0017	0.04	0.01			0.03	0.01			0.01
Watut River catchment	B50		0.02		0.01	0.01			0.01	0.01			0.03
Watut River catchment	B50		0.01		0.01	0.01			0.01	0.01			0.02
Watut River catchment	B50		0.01		0.067	0.07			0.06	0.01			0.02
Watut River catchment	B50		0.01		0.002	0.01			0.004	0.01			0.01
Watut River catchment	B50		0.01		0.022	0.01			0.019	0.07			0.09
Watut River catchment	B50		0.01		0.008	0.05			0.006	0.01			0.03
Watut River catchment	B50		0.04		0.002	0.02			0.002	0.01			0.01
Watut River catchment	B50		0.01		0.024	0.02			0.019	0.054			0.12
Watut River catchment	B50		0.01		0.008	0.01			0.008	0.003			0.03
Watut River catchment	B50		0.01		0.002	0.01			0.002	0.015			0.03
Watut River catchment	B50		0.01		0.004	0.01			0.004	0.021			0.01
Watut River catchment	B50		0.02		0.003	0.01			0.002	0.002			0.01
Watut River catchment	B50		0.01		0.002	0.01			0.005	0.039			0.03
Watut River catchment	B50		0.01		0.002	0.01			0.002	0.006			0.02
Watut River catchment	B50		0.01		0.067	0.07			0.06	0.003			0.02
Watut River catchment	B50		0.01		0.002	0.01			0.004	0.006			0.01
Watut River catchment	B50		0.01		0.022	0.01			0.019	0.005			0.09
Watut River catchment	B50		0.04		0.008	0.05			0.006	0.002			0.03
Watut River catchment	B50		0.01		0.002	0.02			0.002	0.001			0.01
Watut River catchment	B50		0.01		0.024	0.02			0.019	0.054			0.12
Watut River catchment	B50		0.01		0.008	0.01			0.008	0.003			0.03
Watut River catchment	B50		0.088		0.002	0.107			0.002	0.015			0.03
Watut River catchment	B50		0.005		0.004	0.006			0.004	0.021			0.01
Watut River catchment	B50		0.018		0.003	0.034			0.002	0.002			0.21
Watut River catchment	B50		0.034		0.002	0.015			0.005	0.039			0.01
Watut River catchment	B50		0.007		0.002	0.005			0.002	0.006			0.048
Watut River catchment	B50		0.052		0.013	0.053			0.01	0.003			0.041
Watut River catchment	B50		0.01		0.013	0.014			0.011	0.006			0.015
Watut River catchment	B50		0.007		0.001	0.029			0.003	0.005			0.088
Watut River catchment	B50		0.013		49	0.008			0.028	0.002			0.024
Watut River catchment	B50		0.009		0.029	0.004			0.003	0.001			0.008
Watut River catchment	B50		0.006		0.004	0.01			0.002	0.012			0.021
Watut River catchment	B50		0.005		0.003	0.003			0.003	0.01			0.01
Watut River catchment	B50		22		0.003	0.107			0.06	0.007			0.008
Watut River catchment	B50		30		0.068	0.006			0.136	24			0.005
Watut River catchment	B50		0.088		0.148	0.034			0.008	0.036			0.21

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Watut River catchment	B50		0.005		0.009	0.015			0.013	0.003			0.01
Watut River catchment	B50		0.018		0.015	0.005			0.002	0.003			0.048
Watut River catchment	B50		0.034		0.003	0.053			0.017	0.003			0.041
Watut River catchment	B50		0.007		0.021	0.014			0.001	0.046			0.015
Watut River catchment	B50		0.052		0.009	0.029			0.005	0.082			0.088
Watut River catchment	B50		0.01		0.008	0.008			0.144	0.006			0.024
Watut River catchment	B50		0.007		0.127	0.004				0.013			0.008
Watut River catchment	B50		0.013			0.01				0.005			0.021
Watut River catchment	B50		0.009			0.003				0.02			0.01
Watut River catchment	B50		0.006			0.017				0.009			0.008
Watut River catchment	B50		0.005			0.02				0.008			0.005
Watut River catchment	B50		0.018			0.014				0.166			0.04
Watut River catchment	B50		0.014			66							0.03
Watut River catchment	B50		0.009			0.063							0.016
Watut River catchment	B50		0.052			0.005							111
Watut River catchment	B50		0.006			0.005							0.112
Watut River catchment	B50		0.007			0.005							0.023
Watut River catchment	B50		0.005			0.105							0.01
Watut River catchment	B50		0.023			0.206							0.008
Watut River catchment	B50		0.029			0.015							0.18
Watut River catchment	B50		0.01			0.021							0.334
Watut River catchment	B50		0.02			0.005							0.02
Watut River catchment	B50		0.009			0.033							0.052
Watut River catchment	B50		0.031			0.013							0.016
Watut River catchment	B50		0.02			0.011							0.055
Watut River catchment	B50		0.013			0.268							0.034
Watut River catchment	B50		0.09										0.029
Watut River catchment	B50												0.506
Watut River catchment	G1-5		0.0182	0.0003	0.0199	0.0185			0.021	0.0156		0.0001	0.0596
Watut River catchment	G1-5		0.0197	0.0032	0.2145	0.2109			0.2009	0.0927		0.007	0.457
Watut River catchment	G1-5		0.0024	0.00005	0.0181	0.0078			0.01	0.0092		0.0001	0.035
Watut River catchment	G1-5		0.0058	0.0002	0.0063	0.036			0.1515	0.0613		0.0015	0.2086
Watut River catchment	G1-5		0.0198	0.001	0.0268	0.0312			0.0271	0.0245		0.0007	0.0897
Watut River catchment	G1-5		0.0066	0.0001	0.0045	0.0101			0.0083	0.0071		0.0018	0.1283
Watut River catchment	G1-5		0.0179	0.0006	0.0113	0.0167			0.0168	0.0297		0.0001	0.108
Watut River catchment	G1-5		0.0032	0.00005	0.0422	0.006			0.0027	0.0034		0.0025	0.0079
Watut River catchment	G1-5		0.002	0.0005	0.0214	0.0188			0.0267	0.0057		0.0001	0.0079
Watut River catchment	G1-5		0.0218	0.0008	0.0464	0.0343			0.0384	0.0159		0.0001	0.11
Watut River catchment	G1-5		0.0134	0.0026	0.0033	0.0211			0.0167	0.0041		0.0186	0.0587
Watut River catchment	G1-5		0.0206	0.0008	0.0595	0.0195			0.0253	0.0105		0.0278	0.0621
Watut River catchment	G1-5		0.0013	0.0004	0.0457	0.029			0.0137	0.0022		0.0037	0.13
Watut River catchment	G1-5		0.0281	0.0031	0.0159	0.0647			0.0995	0.0254		0.0145	0.139
Watut River catchment	G1-5		0.0511	0.0004	0.145	0.0696			0.0249	0.025		0.0112	0.142
Watut River catchment	G1-5		0.0427	0.0002	0.251	0.0104			0.012	0.0023		0.0523	0.0498
Watut River catchment	G1-5		0.0091	0.0209	0.0312	0.208			0.0942	0.0854		0.0051	0.384
Watut River catchment	G1-5		0.236	0.0141	0.012	0.422			0.177	0.246		0.0057	0.773
Watut River catchment	G1-5		0.074	0.0003	0.028	0.0538			0.0262	0.219		0.0034	0.112
Watut River catchment	G1-5		0.015	0.0003		0.011			0.02	0.0076		0.0002	0.0039
Watut River catchment	G1-5		0.063	0.0005		0.046			0.023	0.027		0.0002	0.011
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.006	0.014	0.0001		0.001	0.001		0.01	0.013
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.017	0.002	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.002	0.0001	0.008	0.002	0.0001		0.001	0.001		0.01	0.034
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.001	0.005	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.002	0.004	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.001	0.004	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.02	0.001	0.0001		0.001	0.001		0.01	0.006
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.01	0.003	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001	0.01	0.001	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001		0.001	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E10		0.001	0.0001		0.002	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001	0.0001	0.009	0.004	0.0015		0.001	0.001		0.01	0.008
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001	0.0001	0.005	0.001	0.0001		0.007	0.001		0.01	0.019
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.007	0.005	0.0001		0.004	0.001		0.01	0.007
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	1	0.001	0.001	0.0001		0.005	8		0.01	0.011
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.002	0.004	0.0001		0.001	0.01		0.01	0.007
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.002	0.0001		0.002	0.01		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	59	0.002	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.003	0.0001	0.01	0.001	0.0001		0.01	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.003	0.0001	0.001	89	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.01	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.01	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001	0.0001	0.001	0.01	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.07
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.001	0.0021		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0026	0.001	0.001	0.0001		0.001	0.001		0.01	0.07
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0001	0.001	0.001	0.0019		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002	0.0003	0.001	0.001	0.0002		0.001	0.006		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001	0.0001	0.002	0.001			0.002	0.007		0.0038	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001		0.0008	0.001			0.0005	0.0055		0.0001	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002		0.0142	0.001			0.0047	0.0026		0.0179	0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002		0.0069	0.001			0.0017			0.0002	0.007
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002		0.0005	0.002			0.001				0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001			0.0156							0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002			0.0212							0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001			0.0049							0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001			0.0002							0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001										0.005
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001										0.0136
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001										0.041
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002										0.0171
Womul River (including the Lower Watut River floodplain) catchment	E20		0.001										0.0007
Womul River (including the Lower Watut River floodplain) catchment	E20		0.002										
Womul River (including the Lower Watut River floodplain) catchment	E20		0.0151										
Womul River (including the Lower Watut River floodplain) catchment	E20		0.0001										
Womul River (including the Lower Watut River floodplain) catchment	E20		0.0069										
Womul River (including the Lower Watut River floodplain) catchment	E20		0.0033										
Womul River (including the Lower Watut River floodplain) catchment	E30		0.01	1	0.01	0.01	0.0001		0.02	6		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30		0.001	0.0001	116	72	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30		0.001	0.0001	0.02	0.01	0.0001		0.001	0.001		0.01	70
Womul River (including the Lower Watut River floodplain) catchment	E30		0.001	0.0003	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30		0.001	0.0002	0.001	0.001			0.003	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30				0.001	0.001						0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30				0.006	0.005						0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E30											0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E30												0.005
Womul River (including the Lower Watut River floodplain) catchment	E30												0.014
Womul River (including the Lower Watut River floodplain) catchment	E30												0.005
Womul River (including the Lower Watut River floodplain) catchment	E40		0.001	1	0.01	85	0.0001		0.001	7		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E40		0.001	0.0001	102	0.001	0.0001		0.001	0.001		0.01	0.45
Womul River (including the Lower Watut River floodplain) catchment	E40		0.001	0.0001	0.01	0.002	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E40		0.001	0.0001	0.001	0.001	0.0001		0.003	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E40			0.0001	0.001	0.003				0.001		0.01	103
Womul River (including the Lower Watut River floodplain) catchment	E40				0.001							0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E40				0.006							0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E40												0.01
Womul River (including the Lower Watut River floodplain) catchment	E40												0.005

Table D
WGJV Surface Water Data
(supplied by BMT WBM)
Baseline

Catchment	Site	Date	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Womul River (including the Lower Watut River floodplain) catchment	E40												0.005
Womul River (including the Lower Watut River floodplain) catchment	E40												0.011
Womul River (including the Lower Watut River floodplain) catchment	E40												0.446
Womul River (including the Lower Watut River floodplain) catchment	E60		0.018	0.0002	0.006	0.011	0.0001		0.005	0.008		0.01	0.017
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.004	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.009
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01	0.0002	0.001	0.001			0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E60		0.009	0.01	0.07	0.001			0.64	0.02		0.01	0.007
Womul River (including the Lower Watut River floodplain) catchment	E60		0.012	0.01	0.07	0.001			0.64	0.02		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E60		0.002			0.001							0.02
Womul River (including the Lower Watut River floodplain) catchment	E60		0.017			0.001							0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.001			0.001							0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.012			0.001							0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.003			0.002							0.89
Womul River (including the Lower Watut River floodplain) catchment	E60		0.004			0.001							0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006			0.31							0.89
Womul River (including the Lower Watut River floodplain) catchment	E60		0.005			0.31							0.01
Womul River (including the Lower Watut River floodplain) catchment	E60		0.008										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.007										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.008										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.004										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.006										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.008										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.02										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E60		0.01										
Womul River (including the Lower Watut River floodplain) catchment	E70		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E70		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E70		0.002	0.0001	0.001	0.001	0.0001		0.001	0.001		0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E70												0.01
Womul River (including the Lower Watut River floodplain) catchment	E70												0.01
Womul River (including the Lower Watut River floodplain) catchment	E70												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80		0.002	0.0001	0.001	0.001	0.0001		0.005	0.001		0.01	0.008
Womul River (including the Lower Watut River floodplain) catchment	E80		0.001	0.0001	0.001	0.002	0.0001		0.001	0.001		0.01	0.013
Womul River (including the Lower Watut River floodplain) catchment	E80		0.001	0.0001	0.001	0.004	0.0001		0.001	0.001		0.01	0.007
Womul River (including the Lower Watut River floodplain) catchment	E80		0.001			0.002			0.001			0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E80		0.01			0.002						0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E80		0.01			0.001						0.01	0.005
Womul River (including the Lower Watut River floodplain) catchment	E80					0.001							0.01
Womul River (including the Lower Watut River floodplain) catchment	E80					0.01							0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01
Womul River (including the Lower Watut River floodplain) catchment	E80												0.01

Note: Results previded as "0" have been removed from the data set as it was not clear whether these were non-detects or otherwise.
Source: WGJV 2006-2016 (Selected Monitoring Sites); BMT WBM in 2013-2016
Source: Raw data tabulated as supplied by BMT WBM sorted as per sample location

Table E
Market Basket Data - Baseline

Draft Market Basket Food contaminant Survey of the Watut-Markam Rivers System Communities.
For Hidden Valley Services Limited. Dr Keith Bentley. Centre of Environmental Health Pty.Ltd.

Metal content of HVSL MBS food samples (all results mg/kg "as received")

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Nauti								
1 Impact	HVFS01	10PE95	Pork flesh	<0.05	0.04	1.7	0.01	< 0.05	0.49	42.7
1 Impact	HVFS03	10PE97	Pork liver	<0.05	0.01	1.1	0.01	< 0.05	0.34	14.1
1 Impact	HVFS04	10PE98	Chicken meat	<0.05	< 0.01	0.7	<0.01	< 0.05	0.17	11.7
1 Impact	HVFS05	10PE99	Banana - ripe	<0.05	< 0.01	0.3	<0.01	< 0.05	< 0.05	1.4
1 Impact	HVFS06	10PE100	Aibika	<0.05	0.02	1.1	<0.01	< 0.05	< 0.05	10.8
1 Impact	HVFS08	10PE102	Sweet potato leaves	<0.05	< 0.01	1	<0.01	< 0.05	< 0.05	2.7
1 Impact	HVFS09	10PE103	Fern fronds	<0.05	< 0.01	2.3	<0.01	< 0.05	< 0.05	6.1
1 Impact	HVFS10	10PE104	Choko tips	<0.05	< 0.01	0.3	<0.01	< 0.05	< 0.05	1.1
1 Impact	HVFS11	10PE105	Pumpkin fruit	<0.05	< 0.01	0.9	<0.01	< 0.05	< 0.05	3.4
1 Impact	HVFS12	10PE106	Sweet corn	<0.05	< 0.01	0.8	<0.01	< 0.05	< 0.05	7.9
1 Impact	HVFS13	10PE107	Beans green	<0.05	< 0.01	0.6	<0.01	< 0.05	< 0.05	5.7
1 Impact	HVFS14	10PE108	Cassava tuber	<0.05	< 0.01	0.6	<0.01	< 0.05	< 0.05	7.9
1 Impact	HVFS15	10PE109	Sweet potato tuber	<0.05	< 0.01	1.1	<0.01	< 0.05	< 0.05	1.6
1 Impact	HVFS16	10PE110	Taro tuber	<0.05	< 0.01	1.3	<0.01	< 0.05	< 0.05	4.1
1 Impact	HVFS17	10PE111	Yam tuber	<0.05	< 0.01	1.6	<0.01	< 0.05	< 0.05	3.5
1 Impact	HVFS19	10PE113	Coconut flesh	<0.05	0.01	4	<0.01	< 0.05	0.29	7.9
1 Impact	HVFS20	10PE114	Peanuts	<0.05	0.02	7.5	<0.01	< 0.05	< 0.05	20.5
1 Impact	HVFS21	10PE115	Citrus	< 0.05	< 0.01	0.4	<0.01	< 0.05	< 0.05	1.5
1 Impact	HVFS22	10PE116	Banana ripe	< 0.05	< 0.01	1	<0.01	< 0.05	< 0.05	2.1
1 Impact	HVFS23	10PE117	Sugar cane	< 0.05	< 0.01	0.1	<0.01	< 0.05	< 0.05	1.6
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Leklu								
1 Impact	HVFS24	10PE118	Pork flesh	0.05	< 0.01	1.5	0.03	< 0.05	0.54	30.9
1 Impact	HVFS25	10PE119	Pork liver	< 0.05	< 0.01	1.1	0.02	< 0.05	0.37	19.2
1 Impact	HVFS26	10PE120	Chicken meat	< 0.05	< 0.01	1.9	0.01	< 0.05	0.26	23.8
1 Impact	HVFS27	10PE121	Aibika	< 0.05	0.01	0.8	< 0.01	< 0.05	< 0.05	3.6
1 Impact	HVFS28	10PE122	Sweet potato leaves	0.18	< 0.01	1.3	0.01	< 0.05	< 0.05	3.7
1 Impact	HVFS29	10PE123	Fern fronds	< 0.05	0.01	1.5	0.01	< 0.05	< 0.05	6.2
1 Impact	HVFS30	10PE124	Choko tips	< 0.05	< 0.01	1.9	<0.01	< 0.05	< 0.05	4.6
1 Impact	HVFS31	10PE125	Pumpkin fruit	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	1.1
1 Impact	HVFS32	10PE126	Sweet corn	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	16.2
1 Impact	HVFS33	10PE127	Beans green	< 0.05	< 0.01	0.5	<0.01	< 0.05	< 0.05	4.5
1 Impact	HVFS34	10PE128	Cassava tuber	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	4
1 Impact	HVFS36	10PE130	Sweet potato tuber	< 0.05	0.01	2.9	<0.01	< 0.05	< 0.05	3.1
1 Impact	HVFS37	10PE131	Taro tuber	< 0.05	< 0.01	1.3	<0.01	< 0.05	< 0.05	53
1 Impact	HVFS38	10PE132	Yam tuber	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	3.1
1 Impact	HVFS40	10PE134	Coconut flesh	< 0.05	0.02	3.6	< 0.01	< 0.05	< 0.05	8.6
1 Impact	HVFS41	10PE135	Peanuts	< 0.05	< 0.01	2.1	< 0.01	< 0.05	< 0.05	19.1
1 Impact	HVFS42	10PE136	Native nuts	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	3.4
1 Impact	HVFS43	10PE137	Citrus	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	0.7
1 Impact	HVFS44	10PE138	Banana ripe	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	1.6
1 Impact	HVFS46	10PE140	Sugar cane	< 0.05	< 0.01	1.2	0.02	< 0.05	0.36	0.7
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Winima								
1 Control	HVFS47	10PE141	Pork flesh	< 0.05	< 0.01	1.2	0.01	< 0.05	0.29	34.1
1 Control	HVFS49	10PE143	Pork liver	< 0.05	< 0.01	0.5	< 0.01	< 0.05	0.4	16.4
1 Control	HVFS50	10PE144	Chicken meat	< 0.05	< 0.01	1.5	<0.01	< 0.05	< 0.05	18
1 Control	HVFS51	10PE145	Banana - ripe	< 0.05	< 0.01	1.3	<0.01	< 0.05	< 0.05	2
1 Control	HVFS52	10PE146	Aibika	< 0.05	< 0.01	2.2	<0.01	< 0.05	< 0.05	8.6
1 Control	HVFS53	10PE147	Sweet potato leaves	< 0.05	0.03	1.7	<0.01	< 0.05	< 0.05	2.7
1 Control	HVFS54	10PE148	Fern fronds	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	3.9
1 Control	HVFS55	10PE149	Choko tips	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	3.7
1 Control	HVFS56	10PE150	Pumpkin fruit	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	2.3
1 Control	HVFS57	10PE151	Sweet corn	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	8.9
1 Control	HVFS58	10PE152	Beans green	< 0.05	< 0.01	1.2	<0.01	< 0.05	< 0.05	2.9
1 Control	HVFS59	10PE153	Cassava tuber	< 0.05	< 0.01	2	< 0.01	< 0.05	< 0.05	7.1
1 Control	HVFS60	10PE154	Sweet potato tuber	< 0.05	0.05	2.1	< 0.01	< 0.05	< 0.05	2.6
1 Control	HVFS61	10PE155	Taro tuber	< 0.05	0.04	1.3	< 0.01	< 0.05	< 0.05	20.9
1 Control	HVFS63	10PE157	Yam tuber	< 0.05	< 0.01	3.9	< 0.01	< 0.05	< 0.05	1.7
1 Control	HVFS65	10PE159	Peanuts	< 0.05	< 0.01	0.5	<0.01	< 0.05	0.05	21.6
1 Control	HVFS66	10PE160	Citrus	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	14.3
1 Control	HVFS67	10PE161	Banana ripe	< 0.05	< 0.01	1.8	< 0.01	< 0.05	< 0.05	2.6
1 Control	HVFS68	10PE162	Sugar cane	0.06	0.01	0.8	0.03	< 0.05	0.28	4.5
1 Control	HVFS69	10PE163	Wild bird flesh	0.06	0.01	1.2	0.03	< 0.05	0.28	13.1

Table E
Market Basket Data - Baseline

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Biawen								
1 Control	HVFS70	10PE164	Pork flesh	< 0.05	< 0.01	1.8	<0.01	< 0.05	0.17	47.8
1 Control	HVFS72	10PE166	Pork liver	< 0.05	< 0.01	1.2	< 0.01	< 0.05	0.16	36.5
1 Control	HVFS73	10PE167	Chicken meat	< 0.05	< 0.01	1.2	< 0.01	< 0.05	0.12	24.7
1 Control	HVFS74	10PE168	Banana - ripe,	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	1.6
1 Control	HVFS75	10PE169	Aibika	< 0.05	0.03	1.4	< 0.01	< 0.05	< 0.05	10.3
1 Control	HVFS76	10PE170	Sweet potato leaves	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	2.4
1 Control	HVFS77	10PE171	Fern fronds	< 0.05	< 0.01	1.5	< 0.01	< 0.05	< 0.05	12.8
1 Control	HVFS78	10PE172	Choko tips	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	2.9
1 Control	HVFS79	10PE173	Pumpkin fruit	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	1.5
1 Control	HVFS80	10PE174	Sweet corn	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	11.9
1 Control	HVFS81	10PE175	Beans green	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	4.3
1 Control	HVFS82	10PE176	Cassava tuber	< 0.05	< 0.01	0.7	< 0.01	0.06	< 0.05	7.1
1 Control	HVFS83	10PE177	Sweet potato tuber	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	3
1 Control	HVFS85	10PE179	Taro tuber	< 0.05	< 0.01	1.7	< 0.01	< 0.05	< 0.05	8.3
1 Control	HVFS86	10PE180	Yam tuber	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	1.8
1 Control	HVFS87	10PE181	Coconut flesh	< 0.05	0.01	4	< 0.01	< 0.05	< 0.05	8.5
1 Control	HVFS88	10PE182	Peanuts	< 0.05	< 0.01	10	< 0.01	< 0.05	0.07	25.9
1 Control	HVFS89	10PE183	Citrus	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	1.1
1 Control	HVFS90	10PE184	Banana ripe	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	3.2
1 Control	HVFS92	10PE186	Sugar cane	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	1.4
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Sambio								
2 Impact	HVFS93	10PE187	Pork flesh	< 0.05	< 0.01	1.1	< 0.01	< 0.05	0.13	25.6
2 Impact	HVFS94	10PE188	Pork liver	< 0.05	0.02	3.3	< 0.01	< 0.05	0.23	38.7
2 Impact	HVFS95	10PE189	Chicken meat	< 0.05	< 0.01	1.9	< 0.01	< 0.05	0.36	40.1
2 Impact	HVFS96	10PE190	Banana ripe	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	2.4
2 Impact	HVFS97	10PE191	Aibika	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	7.1
2 Impact	HVFS98	10PE192	Sweet potato leaves	< 0.05	< 0.01	1.5	< 0.01	< 0.05	< 0.05	3.7
2 Impact	HVFS99	10PE193	Fern fronds	< 0.05	< 0.01	1.4	< 0.01	< 0.05	< 0.05	5.4
2 Impact	HVFS100	10PE194	Choko tips	< 0.05	< 0.01	1.5	< 0.01	< 0.05	< 0.05	3.4
2 Impact	HVFS101	10PE195	Pumpkin fruit	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	2.8
2 Impact	HVFS102	10PE196	Sweet corn	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	7.6
2 Impact	HVFS104	10PE198	Beans, green	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	4.5
2 Impact	HVFS105	10PE199	Cassava tuber	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	5.3
2 Impact	HVFS106	10PE200	Sweet potato tuber	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	2.9
2 Impact	HVFS107	10PE201	Taro tuber	< 0.05	< 0.01	2.1	< 0.01	< 0.05	< 0.05	6.5
2 Impact	HVFS109	10PE203	Yam tuber	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	3.3
2 Impact	HVFS110	10PE204	Coconut flesh	< 0.05	0.01	4.2	< 0.01	< 0.05	< 0.05	9.3
2 Impact	HVFS111	10PE205	Peanuts	< 0.05	0.01	8.4	< 0.01	< 0.05	< 0.05	23.2
2 Impact	HVFS112	10PE206	Native nuts	< 0.05	0.13	4.2	< 0.01	< 0.05	< 0.05	27.7
2 Impact	HVFS113	10PE207	Citrus	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	1.6
2 Impact	HVFS114	10PE208	Banana ripe	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	1.9
2 Impact	HVFS115	10PE209	Sugar cane	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	1.3
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Galowa								
2 Impact	HVFS116	10PE210	Pork flesh	< 0.05	< 0.01	1.4	0.03	< 0.05	0.58	31.7
2 Impact	HVFS117	10PE211	Pork liver	< 0.05	< 0.01	0.9	0.06	< 0.05	0.47	19.2
2 Impact	HVFS118	10PE212	Chicken meat	< 0.05	< 0.01	1	< 0.01	< 0.05	0.32	23.2
2 Impact	HVFS119	10PE213	Aibika	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	6.8
2 Impact	HVFS120	10PE214	Sweet potato leaves	< 0.05	< 0.01	1.1	< 0.01	< 0.05	0.12	2.9
2 Impact	HVFS121	10PE215	Choko tips	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	2.5
2 Impact	HVFS122	10PE216	Pumpkin fruit	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	3
2 Impact	HVFS123	10PE217	Beans, green	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	3.3
2 Impact	HVFS125	10PE219	Cassava tuber	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	6.8
2 Impact	HVFS126	10PE220	Sweet potato tuber	< 0.05	< 0.01	1.8	< 0.01	< 0.05	< 0.05	3
2 Impact	HVFS127	10PE221	Taro tuber	< 0.05	< 0.01	2.2	< 0.01	< 0.05	< 0.05	15.7
2 Impact	HVFS128	10PE222	Yam tuber	< 0.05	< 0.01	1.6	< 0.01	< 0.05	< 0.05	4.2
2 Impact	HVFS130	10PE224	Coconut flesh	< 0.05	0.02	3.7	< 0.01	< 0.05	< 0.05	12.3
2 Impact	HVFS131	10PE225	Native nuts	< 0.05	0.05	5	< 0.01	< 0.05	0.09	27.3
2 Impact	HVFS132	10PE226	Citrus	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	3.2
2 Impact	HVFS133	10PE227	Banana ripe	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	2.3
2 Impact	HVFS134	10PE228	Sugar cane	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	0.8
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Dambi								
2 Impact	HVFS181	10PE275	Aibika	< 0.05	0.02	0.8	< 0.01	< 0.05	< 0.05	4.8
2 Impact	HVFS182	10PE276	Sweet potato leaves	< 0.05	< 0.01	1.4	0.05	< 0.05	< 0.05	3.2
2 Impact	HVFS183	10PE277	Fern fronds	< 0.05	< 0.01	2.6	< 0.01	< 0.05	< 0.05	7.7
2 Impact	HVFS184	10PE278	Choko tips	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	3.6
2 Impact	HVFS185	10PE279	Sweet corn	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	8.4

Table E
Market Basket Data - Baseline

2 Impact	HVFS186	10PE280	Beans, green	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	5.6
2 Impact	HVFS187	10PE281	Cassava tuber	< 0.05	< 0.01	0.4	< 0.01	< 0.05	< 0.05	6.2
2 Impact	HVFS188	10PE282	Sweet potato tuber	< 0.05	< 0.01	1.5	< 0.01	< 0.05	< 0.05	2.7
2 Impact	HVFS190	10PE284	Taro tuber	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	11.1
2 Impact	HVFS191	10PE285	Coconut flesh	< 0.05	< 0.01	4.8	< 0.01	< 0.05	< 0.05	6.6
2 Impact	HVFS192	10PE286	Peanuts	< 0.05	0.02	5.2	< 0.01	< 0.05	< 0.05	20.9
2 Impact	HVFS193	10PE287	Native nuts	< 0.05	0.03	5.9	< 0.01	< 0.05	< 0.05	18.4
2 Impact	HVFS194	10PE288	Citrus	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	1.7
2 Impact	HVFS195	10PE289	Banana ripe	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	2.6
2 Impact	HVFS196	10PE290	Sugar cane	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	0.9
2 Impact	HVFS198	10PE292	Wild mammal flesh	< 0.05	< 0.01	1.3	0.04	< 0.05	0.14	17.8

Table E
Market Basket Data - Baseline

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Patep 1								
2 Control	HVFS135	10PE229	Fish fresh	0.06	< 0.01	0.3	0.2	< 0.05	0.6	18.1
2 Control	HVFS136	10PE230	Pork flesh	< 0.05	< 0.01	1.5	< 0.01	< 0.05	0.21	67.4
2 Control	HVFS138	10PE232	Pork liver	< 0.05	< 0.01	0.9	< 0.01	< 0.05	0.25	17.1
2 Control	HVFS139	10PE233	Chicken meat	< 0.05	< 0.01	1.5	< 0.01	< 0.05	0.24	25.7
2 Control	HVFS140	10PE234	Banana ripe	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	2.7
2 Control	HVFS141	10PE235	Aibika	< 0.05	0.01	1.3	< 0.01	< 0.05	< 0.05	10.2
2 Control	HVFS142	10PE236	Sweet potato leaves	< 0.05	< 0.01	2	< 0.01	< 0.05	< 0.05	3.3
2 Control	HVFS143	10PE237	Fern fronds	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	4.2
2 Control	HVFS144	10PE238	Choko tips	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	2
2 Control	HVFS145	10PE239	Pumpkin fruit	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	1.3
2 Control	HVFS146	10PE240	Sweet corn	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	17.6
2 Control	HVFS147	10PE241	Beans, green	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	3.8
2 Control	HVFS148	10PE242	Cassava tuber	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	2.2
2 Control	HVFS149	10PE243	Sweet potato tuber	< 0.05	< 0.01	1.9	< 0.01	< 0.05	< 0.05	3.3
2 Control	HVFS150	10PE244	Taro tuber	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	3.3
2 Control	HVFS151	10PE245	Yam tuber	< 0.05	< 0.01	1.7	< 0.01	< 0.05	< 0.05	2.8
2 Control	HVFS152	10PE246	Coconut flesh	< 0.05	0.01	3.7	< 0.01	< 0.05	< 0.05	10.1
2 Control	HVFS153	10PE247	Peanuts	< 0.05	< 0.01	6.2	< 0.01	< 0.05	< 0.05	27.3
2 Control	HVFS154	10PE248	Native nuts	< 0.05	< 0.01	3.4	< 0.01	< 0.05	< 0.05	13.9
2 Control	HVFS155	10PE249	Citrus	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	1.6
2 Control	HVFS156	10PE250	Banana ripe	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	1.9
2 Control	HVFS158	10PE252	Sugar cane	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	2.5

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Zamunganga								
2 Control	HVFS159	10PE253	Fish fresh	< 0.05	< 0.01	0.6	0.1	< 0.05	0.55	18.2
2 Control	HVFS160	10PE254	Pork flesh	< 0.05	< 0.01	1.7	< 0.01	< 0.05	0.31	34.3
2 Control	HVFS161	10PE255	Pork liver	< 0.05	< 0.01	1.6	< 0.01	< 0.05	0.43	19.3
2 Control	HVFS162	10PE256	Chicken meat	< 0.05	< 0.01	1.6	< 0.01	< 0.05	0.38	35.6
2 Control	HVFS163	10PE257	Aibika	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	3.1
2 Control	HVFS164	10PE258	Sweet potato leaves	< 0.05	< 0.01	1.7	< 0.01	< 0.05	< 0.05	2.9
2 Control	HVFS165	10PE259	Fern fronds	< 0.05	< 0.01	1	< 0.01	0.06	< 0.05	5.2
2 Control	HVFS166	10PE260	Pumpkin fruit	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	1.2
2 Control	HVFS167	10PE261	Sweet corn	< 0.05	< 0.01	1	< 0.01	< 0.05	0.08	8.3
2 Control	HVFS168	10PE262	Beans, green	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	3.5
2 Control	HVFS169	10PE263	Cassava tuber	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	4.1
2 Control	HVFS170	10PE264	Sweet potato tuber	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	1.5
2 Control	HVFS172	10PE266	Taro tuber	< 0.05	< 0.01	2.1	< 0.01	< 0.05	< 0.05	18.4
2 Control	HVFS173	10PE267	Yam tuber	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	1.8
2 Control	HVFS175	10PE269	Coconut flesh	< 0.05	< 0.01	3.4	< 0.01	< 0.05	0.6	9.7
2 Control	HVFS176	10PE270	Peanuts	< 0.05	0.03	5.9	< 0.01	< 0.05	< 0.05	19.1
2 Control	HVFS177	10PE271	Citrus	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	0.8
2 Control	HVFS179	10PE273	Banana ripe	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	1.5
2 Control	HVFS180	10PE274	Sugar cane	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	0.4

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Matzim (Babwaf)								
3 Impact	HVFS199	10PE293	Fish fresh	0.19	< 0.01	0.4	0.13	< 0.05	0.37	38.3
3 Impact	HVFS200	10PE294	Prawns	0.15	0.1	22.6	0.09	< 0.05	0.55	33.2
3 Impact	HVFS201	10PE295	Pork flesh	0.07	< 0.01	1.3	0.01	< 0.05	0.98	27
3 Impact	HVFS202	10PE296	Pork liver	0.1	0.01	1.1	< 0.01	0.06	0.66	19
3 Impact	HVFS203	10PE297	Chicken meat	< 0.05	< 0.01	0.9	< 0.01	< 0.05	2.4	16.6
3 Impact	HVFS205	10PE299	Banana ripe	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	2.2
3 Impact	HVFS206	10PE300	Aibika	< 0.05	0.02	0.9	< 0.01	< 0.05	0.09	6.7
3 Impact	HVFS207	10PE301	Sweet potato leaves	< 0.05	< 0.01	1.2	< 0.01	< 0.05	0.08	3.4
3 Impact	HVFS208	10PE302	Fern fronds	< 0.05	< 0.01	1.9	< 0.01	< 0.05	< 0.05	6.6
3 Impact	HVFS209	10PE303	Pumpkin fruit	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	1.4
3 Impact	HVFS210	10PE304	Sweet corn	< 0.05	< 0.01	0.5	< 0.01	< 0.05	0.16	8.1
3 Impact	HVFS211	10PE305	Beans, green	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	3.1
3 Impact	HVFS212	10PE306	Sago	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	3.7
3 Impact	HVFS214	10PE308	Cassava tuber	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	4.7
3 Impact	HVFS215	10PE309	Sweet potato tuber	< 0.05	< 0.01	1.4	< 0.01	< 0.05	< 0.05	2.2
3 Impact	HVFS216	10PE310	Taro tuber	< 0.05	< 0.01	1.8	< 0.01	< 0.05	0.06	4.4
3 Impact	HVFS217	10PE311	Yam tuber	< 0.05	< 0.01	2.1	< 0.01	< 0.05	< 0.05	3.4
3 Impact	HVFS218	10PE312	Coconut flesh	< 0.05	0.05	4.8	< 0.01	< 0.05	0.35	10.1
3 Impact	HVFS219	10PE313	Peanuts	< 0.05	0.05	5.1	< 0.01	< 0.05	0.61	24.8
3 Impact	HVFS220	10PE314	Citrus	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	1.5
3 Impact	HVFS221	10PE315	Banana ripe	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	1.8
3 Impact	HVFS223	10PE317	Sugar cane	< 0.05	< 0.01	0.2	< 0.01	< 0.05	< 0.05	0.3
3 Impact	HVFS224	10PE318	Mango fruit	< 0.05	< 0.01	0.4	< 0.01	< 0.05	< 0.05	0.7
3 Impact	HVFS225	10PE319	Turtle flesh	0.21	0.01	1.4	0.07	< 0.05	0.38	51.5
3 Impact	HVFS226	10PE320	Reptile flesh	< 0.05	< 0.01	0.8	0.02	< 0.05	1.01	25.7

Table E
Market Basket Data - Baseline

3 Impact	HVFS227	10PE321	Wild mammal flesh	0.05	< 0.01	1.1	0.11	< 0.05	0.69	20.2
3 Impact	HVFS228	10PE322	Wild bird flesh	< 0.05	< 0.01	2.3	< 0.01	< 0.05	0.36	26.5

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Uruf								
3 Impact	HVFS229	10PE323	Fish fresh	< 0.05	< 0.01	0.5	0.11	< 0.05	0.37	6.4
3 Impact	HVFS230	10PE324	Prawns	0.12	< 0.01	9	< 0.01	< 0.05	0.36	19.1
3 Impact	HVFS231	10PE325	Pork flesh	0.07	< 0.01	1.7	< 0.01	< 0.05	0.73	36.1
3 Impact	HVFS232	10PE326	Pork liver	< 0.05	< 0.01	1	< 0.01	< 0.05	0.49	19.9
3 Impact	HVFS233	10PE327	Chicken meat	< 0.05	< 0.01	0.9	< 0.01	< 0.05	1.16	21.1
3 Impact	HVFS234	10PE328	Banana ripe	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	1.4
3 Impact	HVFS235	10PE329	Aibika	< 0.05	0.01	1.4	< 0.01	< 0.05	< 0.05	8.4
3 Impact	HVFS236	10PE330	Sweet potato leaves	< 0.05	< 0.01	1.7	< 0.01	< 0.05	< 0.05	4.7
3 Impact	HVFS237	10PE331	Fern fronds	< 0.05	0.01	1.5	< 0.01	< 0.05	< 0.05	4.4
3 Impact	HVFS238	10PE332	Pumpkin fruit	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	1
3 Impact	HVFS239	10PE333	Sweet corn	< 0.05	< 0.01	0.9	< 0.01	< 0.05	0.09	11.5
3 Impact	HVFS241	10PE335	Beans, green	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	3.4
3 Impact	HVFS242	10PE336	Sago	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	1.5
3 Impact	HVFS243	10PE337	Sweet potato tuber	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	2.5
3 Impact	HVFS244	10PE338	Taro tuber	< 0.05	< 0.01	1.7	< 0.01	< 0.05	< 0.05	4.8
3 Impact	HVFS245	10PE339	Yam tuber	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	5
3 Impact	HVFS246	10PE340	Coconut flesh	< 0.05	0.03	4.6	< 0.01	< 0.05	0.19	8.9
3 Impact	HVFS247	10PE341	Peanuts	< 0.05	0.02	8.8	< 0.01	< 0.05	0.62	30.4
3 Impact	HVFS248	10PE342	Citrus	< 0.05	< 0.01	1	< 0.01	< 0.05	< 0.05	2.8
3 Impact	HVFS249	10PE343	Banana ripe	< 0.05	< 0.01	0.7	< 0.01	< 0.05	< 0.05	1.7
3 Impact	HVFS250	10PE344	Sugar cane	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	1.9
3 Impact	HVFS252	10PE346	Mango fruit	< 0.05	< 0.01	2.4	< 0.01	< 0.05	< 0.05	1.5
3 Impact	HVFS253	10PE347	Turtle flesh	0.06	< 0.01	0.7	< 0.01	< 0.05	0.75	25.1
3 Impact	HVFS254	10PE348	Wild mammal flesh	< 0.05	< 0.01	0.8	0.05	< 0.05	0.3	17.1

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Wampan								
3 Control	HVFS255	10PE349	Molluscs	1.05	0.1	3.2	0.04	0.11	0.54	120.9
3 Control	HVFS256	10PE350	Pork flesh	< 0.05	< 0.01	1.3	< 0.01	< 0.05	0.12	26.4
3 Control	HVFS257	10PE351	Pork liver	< 0.05	< 0.01	1.1	< 0.01	< 0.05	0.2	19.6
3 Control	HVFS258	10PE352	Banana ripe	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	1.4
3 Control	HVFS259	10PE353	Aibika	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	9
3 Control	HVFS260	10PE354	Sweet potato leaves	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	3
3 Control	HVFS261	10PE355	Fern fronds	< 0.05	< 0.01	2.1	< 0.01	< 0.05	< 0.05	6.8
3 Control	HVFS262	10PE356	Choko tips	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	2.8
3 Control	HVFS263	10PE357	Pumpkin fruit	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	2.1
3 Control	HVFS264	10PE358	Sweet corn	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	8.2
3 Control	HVFS266	10PE360	Beans, green	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	2.7
3 Control	HVFS267	10PE361	Sago	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	0.7
3 Control	HVFS268	10PE362	Cassava tuber	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	6.1
3 Control	HVFS269	10PE363	Sweet potato tuber	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	2.6
3 Control	HVFS271	10PE365	Taro tuber	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	4.2
3 Control	HVFS272	10PE366	Yam tuber	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	2.9
3 Control	HVFS273	10PE367	Coconut flesh	< 0.05	< 0.01	5.3	< 0.01	< 0.05	< 0.05	10.6
3 Control	HVFS274	10PE368	Peanuts	< 0.05	< 0.01	8.1	< 0.01	< 0.05	< 0.05	29.1
3 Control	HVFS275	10PE369	Citrus	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	1.3
3 Control	HVFS276	10PE370	Banana ripe	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	2.4
3 Control	HVFS277	10PE371	Sugar cane	< 0.05	< 0.01	0.1	< 0.01	< 0.05	< 0.05	0.4
3 Control	HVFS278	10PE372	Mango fruit	< 0.05	< 0.01	1.2	< 0.01	< 0.05	0.06	22.6
3 Control	HVFS279	10PE373	Wild mammal flesh	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	0.5
3 Control	HVFS280	10PE374	Wild bird flesh	< 0.05	< 0.01	1.2	0.01	< 0.05	0.13	17.7
3 Control	HVFS281	10PE375	Chicken meat	< 0.05	< 0.01	0.9	< 0.01	< 0.05	0.22	18.9

Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Gingen								
3 Control	HVFS282	10PE376	Fish fresh	< 0.05	< 0.01	0.4	0.47	< 0.05	0.45	13.3
3 Control	HVFS283	10PE377	Prawns	< 0.05	< 0.01	4.7	0.11	< 0.05	0.64	16.7
3 Control	HVFS284	10PE378	Pork flesh	< 0.05	< 0.01	1	0.02	< 0.05	0.31	31.5
3 Control	HVFS285	10PE379	Pork liver	< 0.05	< 0.01	0.9	<0.01	< 0.05	0.28	14.3
3 Control	HVFS286	10PE380	Chicken meat	< 0.05	< 0.01	1.1	< 0.01	< 0.05	0.25	13.4
3 Control	HVFS288	10PE382	Aibika	< 0.05	< 0.01	0.8	< 0.01	< 0.05	< 0.05	8.1
3 Control	HVFS289	10PE383	Sweet potato leaves	< 0.05	< 0.01	1.5	< 0.01	< 0.05	< 0.05	2.6
3 Control	HVFS290	10PE384	Fern fronds	< 0.05	< 0.01	1.8	< 0.01	< 0.05	< 0.05	6.9
3 Control	HVFS291	10PE385	Choko tips	< 0.05	< 0.01	0.9	< 0.01	< 0.05	< 0.05	3.5
3 Control	HVFS292	10PE386	Pumpkin fruit	< 0.05	< 0.01	0.3	< 0.01	< 0.05	< 0.05	1.4
3 Control	HVFS293	10PE387	Sweet corn	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	10.5
3 Control	HVFS294	10PE388	Beans, green	< 0.05	< 0.01	0.6	< 0.01	< 0.05	< 0.05	2.3
3 Control	HVFS296	10PE390	Cassava tuber	< 0.05	< 0.01	0.5	< 0.01	< 0.05	< 0.05	7.8
3 Control	HVFS297	10PE391	Sweet potato tuber	< 0.05	< 0.01	1.3	< 0.01	< 0.05	< 0.05	2.4
3 Control	HVFS298	10PE392	Taro tuber	< 0.05	< 0.01	1.1	< 0.01	< 0.05	< 0.05	16.6

Table E
Market Basket Data - Baseline

3 Control	HVFS299	10PE393	Yam tuber	< 0.05	< 0.01	1.2	< 0.01	< 0.05	< 0.05	3.8
3 Control	HVFS300	10PE394	Coconut flesh	< 0.05	0.01	5.4	< 0.01	< 0.05	0.11	19.6
3 Control	HVFS301	10PE395	Peanuts	< 0.05	<0.01	5.4	< 0.01	< 0.05	< 0.05	17
3 Control	HVFS302	10PE396	Native nuts	< 0.05	0.04	6.1	< 0.01	< 0.05	< 0.05	29
3 Control	HVFS303	10PE397	Citrus	< 0.05	<0.01	0.4	< 0.01	< 0.05	<0.05	1
3 Control	HVFS304	10PE398	Banana ripe	< 0.05	<0.01	0.9	< 0.01	< 0.05	0.01	2
3 Control	HVFS305	10PE399	Sugar cane	< 0.05	<0.01	0.1	< 0.01	< 0.05	<0.05	1
3 Control	HVFS306	10PE400	Turtle flesh	0.07	<0.01	1.1	0.09	< 0.05	0.32	38.7
3 Control	HVFS307	10PE401	Wild mammal flesh	< 0.05	<0.01	1	0.07	< 0.05	0.3	21.6
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Labu 1								
4 Impact	HVFS308	10PE402	Fish fresh	< 0.05	<0.01	0.1	0.1	< 0.05	0.29	4
4 Impact	HVFS309	10PE403	Prawns	0.18	0.02	6.5	< 0.01	< 0.05	0.45	17.5
4 Impact	HVFS310	10PE404	Molluscs	1.2	0.18	27	0.08	0.26	0.55	169
4 Impact	HVFS311	10PE405	Pork flesh	< 0.05	<0.01	1.1	< 0.01	< 0.05	0.42	31.9
4 Impact	HVFS313	10PE407	Pork liver	< 0.05	<0.01	1.1	< 0.01	< 0.05	0.4	15.1
4 Impact	HVFS314	10PE408	Chicken meat	< 0.05	<0.01	0.7	0.02	< 0.05	0.26	10.4
4 Impact	HVFS315	10PE409	Aibika	< 0.05	0.01	1.1	< 0.01	0.06	<0.05	7
4 Impact	HVFS316	10PE410	Sweet potato leaves	< 0.05	<0.01	1.1	< 0.01	< 0.05	<0.05	2.9
4 Impact	HVFS317	10PE411	Fern fronds	< 0.05	<0.01	1.6	< 0.01	< 0.05	<0.05	5.4
4 Impact	HVFS318	10PE412	Pumpkin fruit	< 0.05	<0.01	0.5	< 0.01	< 0.05	<0.05	1.8
4 Impact	HVFS319	10PE413	Sweet corn	< 0.05	<0.01	0.8	< 0.01	< 0.05	<0.05	8.7
4 Impact	HVFS320	10PE414	Beans, green	< 0.05	<0.01	0.9	< 0.01	< 0.05	<0.05	2.2
4 Impact	HVFS321	10PE415	Sago	< 0.05	<0.01	0.3	< 0.01	< 0.05	<0.05	0.4
4 Impact	HVFS322	10PE416	Cassava tuber	< 0.05	<0.01	0.6	< 0.01	< 0.05	<0.05	4.9
4 Impact	HVFS323	10PE417	Sweet potato tuber	< 0.05	<0.01	1.3	< 0.01	< 0.05	<0.05	2.4
4 Impact	HVFS324	10PE418	Taro tuber	< 0.05	<0.01	1.3	< 0.01	< 0.05	<0.05	5.3
4 Impact	HVFS325	10PE419	Yam tuber	< 0.05	<0.01	1.9	< 0.01	< 0.05	<0.05	7.2
4 Impact	HVFS326	10PE420	Coconut flesh	< 0.05	<0.01	6.9	< 0.01	< 0.05	<0.05	9.8
4 Impact	HVFS327	10PE421	Peanuts	< 0.05	0.03	7.6	< 0.01	< 0.05	0.38	26.8
4 Impact	HVFS328	10PE422	Native nuts	< 0.05	<0.01	15.8	< 0.01	< 0.05	0.17	18.8
4 Impact	HVFS329	10PE423	Citrus	< 0.05	<0.01	0.5	< 0.01	< 0.05	<0.05	0.9
4 Impact	HVFS330	10PE424	Banana ripe	< 0.05	<0.01	0.7	< 0.01	< 0.05	<0.05	2.4
4 Impact	HVFS332	10PE426	Sugar cane	< 0.05	<0.01	0.3	< 0.01	< 0.05	<0.05	2
4 Impact	HVFS333	10PE427	Mango fruit	< 0.05	<0.01	0.7	< 0.01	< 0.05	<0.05	1
4 Impact	HVFS334	10PE428	Reptile flesh	< 0.05	<0.01	1	0.01	< 0.05	0.13	41.7
4 Impact	HVFS335	10PE429	Wild mammal flesh	0.05	<0.01	0.8	0.05	< 0.05	0.17	19
4 Impact	HVFS336	10PE430	Wild bird flesh	< 0.05	<0.01	4.1	0.12	< 0.05	0.34	13.8
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Gabmazung								
4 Impact	HVFS379	10PE473	Fish fresh	< 0.05	< 0.01	0.2	0.05	<0.05	0.41	10.4
4 Impact	HVFS380	10PE474	Pork flesh	< 0.05	< 0.01	1.5	<0.01	<0.05	0.59	58.7
4 Impact	HVFS381	10PE475	Pork liver	< 0.05	< 0.01	1.6	<0.01	<0.05	0.44	18
4 Impact	HVFS382	10PE476	Chicken meat	< 0.05	< 0.01	1	<0.01	<0.05	0.5	23.1
4 Impact	HVFS383	10PE477	Banana ripe	< 0.05	< 0.01	0.7	<0.01	<0.05	<0.05	1.9
4 Impact	HVFS384	10PE478	Aibika	< 0.05	< 0.01	0.7	<0.01	<0.05	<0.05	6
4 Impact	HVFS385	10PE479	Sweet potato leaves	< 0.05	< 0.01	1.7	<0.01	<0.05	<0.05	3.3
4 Impact	HVFS386	10PE480	Fern fronds	< 0.05	< 0.01	1.7	<0.01	<0.05	<0.05	7.3
4 Impact	HVFS387	10PE481	Pumpkin fruit	< 0.05	< 0.01	0.5	<0.01	<0.05	<0.05	0.5
4 Impact	HVFS388	10PE482	Sweet corn	< 0.05	< 0.01	1.3	<0.01	<0.05	<0.05	10.5
4 Impact	HVFS389	10PE483	Beans, green	< 0.05	< 0.01	1.1	<0.01	<0.05	<0.05	1.9
4 Impact	HVFS390	10PE484	Cassava tuber	< 0.05	0.02	0.7	<0.01	<0.05	<0.05	4.2
4 Impact	HVFS391	10PE485	Sweet potato tuber	< 0.05	< 0.01	1.7	<0.01	<0.05	<0.05	2.8
4 Impact	HVFS392	10PE486	Taro tuber	< 0.05	< 0.01	3	<0.01	<0.05	<0.05	1.1
4 Impact	HVFS394	10PE488	Yam tuber	< 0.05	< 0.01	1.1	<0.01	<0.05	<0.05	3.9
4 Impact	HVFS395	10PE489	Coconut flesh	< 0.05	< 0.01	3.7	<0.01	<0.05	<0.05	6.9
4 Impact	HVFS396	10PE490	Peanuts	< 0.05	0.01	3.5	<0.01	<0.05	0.2	10.9
4 Impact	HVFS397	10PE491	Citrus	< 0.05	< 0.01	0.6	<0.01	<0.05	<0.05	0.8
4 Impact	HVFS398	10PE492	Banana ripe	< 0.05	< 0.01	1	<0.01	<0.05	<0.05	1.3
4 Impact	HVFS399	10PE493	Sugar cane	< 0.05	< 0.01	0.2	<0.01	<0.05	<0.05	0.1
4 Impact	HVFS400	10PE494	Mango fruit	< 0.05	< 0.01	0.8	<0.01	<0.05	<0.05	0.6
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Labu 3								
4 Control	HVFS337	10PE431	Fish fresh	3.5	<0.01	0.4	0.14	< 0.05	0.83	6.4
4 Control	HVFS338	10PE432	Molluscs	0.53	0.07	5.1	0.04	0.39	0.7	85.4
4 Control	HVFS339	10PE433	Chicken meat	< 0.05	<0.01	1.3	< 0.01	< 0.05	0.22	27.6
4 Control	HVFS340	10PE434	Aibika	< 0.05	0.04	0.8	< 0.01	< 0.05	<0.05	8.3
4 Control	HVFS341	10PE435	Sweet potato leaves	< 0.05	<0.01	1.1	< 0.01	< 0.05	<0.05	2.7
4 Control	HVFS342	10PE436	Fern fronds	< 0.05	0.01	2.1	< 0.01	< 0.05	<0.05	14.3
4 Control	HVFS343	10PE437	Pumpkin fruit	< 0.05	<0.01	0.5	< 0.01	< 0.05	<0.05	0.9
4 Control	HVFS344	10PE438	Sago	< 0.05	<0.01	0.1	< 0.01	< 0.05	<0.05	1.5
4 Control	HVFS346	10PE440	Cassava tuber	< 0.05	<0.01	0.5	< 0.01	< 0.05	<0.05	3.9

Table E
Market Basket Data - Baseline

4 Control	HVFS347	10PE441	Sweet potato tuber	< 0.05	<0.01	2.1	< 0.01	< 0.05	<0.05	4.8
4 Control	HVFS348	10PE442	Coconut flesh	< 0.05	<0.01	5	< 0.01	< 0.05	<0.05	9.1
4 Control	HVFS349	10PE443	Citrus	< 0.05	<0.01	0.4	< 0.01	< 0.05	<0.05	1
4 Control	HVFS350	10PE444	Banana ripe	< 0.05	<0.01	1	< 0.01	< 0.05	<0.05	1.9
Region	Client ID	Laboratory ID	Food commodity	Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc
		Wampit								
4 Control	HVFS351	10PE445	Fish fresh	0.12	<0.01	0.4	0.2	< 0.05	0.43	15.8
4 Control	HVFS352	10PE446	Prawns	< 0.05	0.01	11.9	0.01	< 0.06	0.71	16.5
4 Control	HVFS353	10PE447	Pork flesh	< 0.05	<0.01	1.4	< 0.01	< 0.05	0.52	60
4 Control	HVFS354	10PE448	Pork liver	< 0.05	0.01	1.1	< 0.01	< 0.05	0.37	19.4
4 Control	HVFS355	10PE449	Chicken meat	< 0.05	<0.01	0.8	< 0.01	< 0.05	0.42	11.7
4 Control	HVFS356	10PE450	Banana ripe	< 0.05	<0.01	0.7	< 0.01	< 0.05	<0.05	1.7
4 Control	HVFS357	10PE451	Aibika	< 0.05	0.01	0.9	<0.01	<0.05	0.15	10.2
4 Control	HVFS358	10PE452	Sweet potato leaves	< 0.05	< 0.01	1.3	<0.01	<0.05	<0.05	3.3
4 Control	HVFS359	10PE453	Fern fronds	< 0.05	< 0.01	2	<0.01	<0.05	<0.05	6.8
4 Control	HVFS360	10PE454	Choko tips	< 0.05	< 0.01	1.9	<0.01	<0.05	<0.05	3.2
4 Control	HVFS361	10PE455	Pumpkin fruit	< 0.05	< 0.01	0.6	<0.01	<0.05	<0.05	1.5
4 Control	HVFS362	10PE456	Sweet corn	< 0.05	< 0.01	1	<0.01	<0.05	<0.05	7.7
4 Control	HVFS363	10PE457	Beans, green	< 0.05	< 0.01	1	<0.01	<0.05	<0.05	5.3
4 Control	HVFS364	10PE458	Sago	< 0.05	0.01	0.3	<0.01	<0.05	<0.05	0.6
4 Control	HVFS365	10PE459	Cassava tuber	< 0.05	< 0.01	0.7	<0.01	<0.05	<0.05	3
4 Control	HVFS366	10PE460	Sweet potato tuber	< 0.05	< 0.01	1.3	<0.01	<0.05	<0.05	2.2
4 Control	HVFS367	10PE461	Taro tuber	< 0.05	< 0.01	1.6	<0.01	<0.05	<0.05	5.3
4 Control	HVFS368	10PE462	Yam tuber	< 0.05	< 0.01	1.1	<0.01	<0.05	<0.05	3.9
4 Control	HVFS370	10PE464	Coconut flesh	< 0.05	0.01	4.7	<0.01	<0.05	0.05	8
4 Control	HVFS371	10PE465	Peanuts	< 0.05	0.04	3.3	<0.01	<0.05	<0.05	14.9
4 Control	HVFS372	10PE466	Citrus	< 0.05	< 0.01	0.6	<0.01	<0.05	<0.05	1.2
4 Control	HVFS373	10PE467	Banana ripe	< 0.05	< 0.01	1	<0.01	<0.05	<0.05	1.8
4 Control	HVFS374	10PE468	Sugar cane	< 0.05	< 0.01	0.1	<0.01	<0.05	<0.05	0.2
4 Control	HVFS375	10PE469	Mango fruit	< 0.05	< 0.01	0.9	<0.01	<0.05	<0.05	1.2
4 Control	HVFS376	10PE470	Turtle flesh	0.06	< 0.01	0.9	0.02	<0.05	0.4	36.9
4 Control	HVFS377	10PE471	Wild mammal flesh	0.05	< 0.01	0.6	0.14	<0.05	0.48	19.1
4 Control	HVFS378	10PE472	Wild bird flesh	< 0.05	< 0.01	1.4	0.01	<0.05	0.29	41.6

Table F
Ok Tedi Mine Regions: Food Consumption Data - Baseline

Regional food consumption by age group (all values grams per week)

Food commodity	Age group				Age group				Age group				Age group				Age group			
	12 – 60 months	5 – 10	11 - 15	Adult	12 – 60 months	5 – 10	11 - 15	Adult	12 – 60 months	5 – 10	11 - 15	Adult	12 – 60 months	5 – 10	11 - 15	Adult	12 – 60 months	5 – 10	11 - 15	Adult
	Region 1				**Region 2**				**Region 3**				**Region 4**				**Region 5**			
Sweet potato	746	1296	1176	1582	1490	545	572	1062	225	315	522	362	0	231	723	223	335	280	433	278
Cassava	117	121	18	202	387	257	117	363	265	377	415	223	1528	953	445	748	0	15	50	26
Taro	403	972	403	387	790	486	684	801	93	214	130	201	0	117	0	68				
Yam	0	0	608	0	499	546	245	646	701	1107	504	929	385	1297	223	1222	1184	601	448	491
Irish potato	0	53	0	16																
Banana	362	571	536	1101	1998	2269	2889	2881	1684	778	785	1580	0	144	21	218	734	492	826	524
Rice	2119	1817	3005	3069	155	200	249	232	0	0	0	24	385	425	1545	477	389	1105	1494	1431
Sago	40	128	13	27	500	706	480	1049	2828	2614	2220	3341	1983	1407	1961	1427	1377	824	1007	936
Coconut	0	25	50	29	13	26	47	14	356	529	603	319	114	30	0	31	47	69	52	90
Pork	0	99	200	72					440	395	363	358	0	2	0	23	23	19	14	16
Lamb	0	0	0	16																
Chicken	320	312	479	817	0	0	70	39												
All other meats					121	39	58	27	295	867	1160	572	712	586	530	608	70	116	188	141
Fresh fish	0	51	44	24	0	21	31	22	1619	2219	2564	2392	0	4	16	9	54	119	146	377
Smoked fish													58	53	54	96	136	173	162	169
Prawn/shrimps													0	0	111	16	58	83	126	50
Sugar cane	53	0	0	48	194	136	0	79	137	280	309	510								
Fresh fruit					225	213	0	60	86	86	77	60								
Peanut and local nuts	13	0	0	3																
Aibika/other green vegetables	373	576	1018	918	988	957	1194	1206	292	480	1552	581	35	22	196	102	277	131	132	301
Yellow vegetables	0	0	25	13	32	13	0	0	85	132	65	183	1050	579	233	254	241	200	214	159
Flour	40	42	0	126									0	0	83	30	156	437	458	616
Tinned meat	73	115	53	32	92	23	16	38									0	0	0	10
Tinned fish	185	155	628	308	17	21	31	26									35	46	23	34
Milk/Milk powdered	10	13	13	35													0	0	6	7
Sugar	27	34	28	92													23	85	118	168
Bread and other cereals	349	170	213	202	0	16	114	19									0	27	36	48
Biscuits	57	117	318	204					7	19	63	20					0	10	97	19
Eggs					98	80	0	0	13	39	19	5								
Total food consumption (grams)	5289	6665	8827	9323	7599	6553	6797	8563	9126	10451	11351	11660	6250	5851	6141	5551	5140	4831	6031	5893

Notes:

1.There were no adolescents monitored at the villages in Region 3. This data has been conducted as discussed in the text.

2.The number of person days represented in each of the tables varies between regions and age groups (see Table 4).

Source: Ok Tedi Mine Limited Community Health Study Volume 1. Centre for Environmental Health Pty Ltd. 17 May 2007

Table G
Freshwater Biota Data - Baseline

Fish Tissue Analysis

			Aluminium	Arsenic	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Zinc
		Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
		PQL (where noted)	0.5	0.05	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.05	0.02	0.01
Site/ID	**Sample Date**													
NQ15/00935	5/03/2015		<0.5	<0.05	<0.01	<0.05	0.47	0.018	0.4	0.074	<0.01	0.19	<0.02	13
NQ15/00936	5/03/2015		<0.5	<0.05	<0.01	<0.05	0.42	0.024	0.28	0.056	<0.01	0.19	<0.02	13
NQ15/00937	5/03/2015		2.5	<0.05	<0.01	<0.05	0.36	0.016	1.3	0.058	<0.01	0.15	<0.02	29
NQ15/00938	5/03/2015		2	<0.05	<0.01	<0.05	0.41	0.039	2.4	0.049	0.02	0.13	<0.02	45
NQ15/00939	5/03/2015		2.9	<0.05	<0.01	<0.05	0.45	0.025	1.8	0.04	0.023	0.13	<0.02	39
NQ15/00940	5/03/2015		17	<0.05	<0.01	<0.05	0.6	0.051	2.3	0.039	0.041	0.19	<0.02	38
NQ15/00941	5/03/2015		8.5	<0.05	<0.01	<0.05	0.5	0.037	2.6	0.038	0.02	0.16	<0.02	32
NQ15/00942	5/03/2015		<0.5	<0.05	<0.01	<0.05	0.18	<0.01	0.48	0.11	<0.01	0.15	<0.02	11
NQ15/00943	5/03/2015		<0.5	<0.05	<0.01	<0.05	0.19	<0.01	0.44	0.15	<0.01	0.14	<0.02	9.2
NQ15/00944	5/03/2015		<0.5	<0.05	<0.01	<0.05	0.27	<0.01	0.3	0.061	<0.01	0.17	<0.02	8
NQ15/00945	5/03/2015		1.2	<0.05	<0.01	<0.05	0.33	0.011	1.6	0.052	0.029	0.17	<0.02	13
NQ15/00946	5/03/2015		3.6	<0.05	<0.01	<0.05	0.37	0.011	1.5	0.033	0.017	0.16	<0.02	13
NQ15/00947	7/03/2015		1.1	<0.05	0.01	0.068	0.53	0.016	0.91	0.022	0.032	0.39	<0.02	16
NQ15/00948	7/03/2015		<0.5	<0.05	0.029	<0.05	0.51	<0.01	0.43	0.023	0.026	0.25	<0.02	10
NQ15/00949	7/03/2015		0.61	<0.05	0.026	<0.05	0.64	<0.01	0.48	0.026	0.065	0.32	<0.02	8.8
NQ15/00950	7/03/2015		0.58	<0.05	0.081	<0.05	0.5	0.014	1.3	0.024	0.075	0.39	<0.02	10
NQ15/00951	7/03/2015		0.79	<0.05	0.043	<0.05	0.65	0.014	0.85	0.028	0.071	0.28	<0.02	8.6
NQ15/00952	11/03/2015		3.9	<0.05	<0.01	<0.05	0.42	0.015	3.2	0.011	0.023	0.18	<0.02	54
NQ15/00953	11/03/2015		3.8	0.052	<0.01	<0.05	0.41	0.018	3.2	0.014	0.017	0.15	<0.02	52
NQ15/00954	11/03/2015		1.9	<0.05	<0.01	<0.05	0.3	<0.01	6.8	0.039	<0.01	0.12	<0.02	43
NQ15/00955	11/03/2015		1.8	<0.05	<0.01	<0.05	0.4	0.01	2.2	0.02	<0.01	0.17	<0.02	48
NQ15/00956	11/03/2015		1.6	<0.05	<0.01	<0.05	0.42	0.029	2.3	0.016	0.01	0.18	<0.02	48
NQ15/00957	11/03/2015		10	0.85	<0.01	<0.05	0.38	0.022	10	<0.01	0.068	15	<0.02	17
NQ15/00958	11/03/2015		5.1	0.44	<0.01	0.059	0.34	<0.01	5.4	<0.01	0.036	0.091	<0.02	16
NQ15/00959	11/03/2015		2.4	0.43	<0.01	<0.05	0.22	<0.01	1.2	<0.01	0.024	0.12	<0.02	9.8
NQ15/00960	11/03/2015		1.9	0.26	<0.01	<0.05	0.25	0.017	4.2	<0.01	<0.01	0.066	<0.02	7.2
NQ15/00961	11/03/2015		1.9	0.12	<0.01	<0.05	0.12	0.011	0.5	<0.01	<0.01	0.052	<0.02	4.3
NQ15/00962	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.29	<0.01	1.4	0.2	<0.01	0.19	<0.02	27
NQ15/00963	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.51	<0.01	3.3	0.2	<0.01	0.21	<0.02	36
NQ15/00964	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.44	<0.01	2.2	0.16	<0.01	0.2	<0.02	41
NQ15/00965	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.43	<0.01	1.8	0.12	<0.01	0.2	<0.02	37
NQ15/00966	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.43	<0.01	2	0.27	<0.01	0.22	<0.02	35
NQ15/00967	11/03/2015		<0.5	<0.05	<0.01	<0.05	0.2	<0.01	0.92	0.19	<0.01	0.24	<0.02	9.7
NQ15/00968	11/03/2015		1.3	<0.05	<0.01	<0.05	0.28	<0.01	5.3	0.1	0.023	0.38	<0.02	15
NQ15/00969	11/03/2015		0.67	<0.05	<0.01	<0.05	0.32	<0.01	1	0.084	<0.01	0.25	<0.02	25
NQ15/00970	12/03/2015		3.9	<0.05	<0.01	0.088	0.58	<0.01	5.9	0.074	0.025	0.21	<0.02	35
NQ15/00971	12/03/2015		3.5	<0.05	<0.01	<0.05	0.32	<0.01	4.2	0.044	0.02	0.15	<0.02	32
NQ15/00972	12/03/2015		2.3	<0.05	<0.01	<0.05	0.43	0.013	6.2	0.04	0.027	0.16	<0.02	34
NQ15/00973	12/03/2015		3.7	<0.05	<0.01	<0.05	0.5	0.012	6.5	0.037	0.024	0.18	<0.02	35
NQ15/00974	12/03/2015		0.8	0.07	<0.01	<0.05	0.24	0.011	0.76	0.097	<0.01	0.59	<0.02	16
NQ15/00975	12/03/2015		2.1	<0.05	<0.01	<0.05	0.2	<0.01	3.6	0.075	<0.01	0.16	<0.02	17
NQ15/00976	12/03/2015		0.66	<0.05	<0.01	<0.05	0.28	<0.01	2.5	0.042	<0.01	0.2	<0.02	14
NQ15/00977	12/03/2015		0.99	<0.05	<0.01	<0.05	0.26	<0.01	3.6	0.07	<0.01	0.2	<0.02	15
NQ15/00978	12/03/2015		2.3	0.076	<0.01	<0.05	0.28	0.018	7.2	0.087	0.013	0.5	<0.02	31
NQ15/00979	12/03/2015		53	<0.05	<0.01	0.092	0.57	0.01	2.3	0.022	0.052	0.19	<0.02	13
NQ15/00980	13/03/2015		87	<0.05	<0.01	0.25	0.49	0.02	4.5	0.037	0.14	0.27	<0.02	13
NQ15/00981	13/03/2015		38	<0.05	<0.01	0.081	0.53	0.014	1.9	0.087	0.06	0.21	<0.02	11
NQ15/00982	13/03/2015		72	<0.05	<0.01	0.51	0.56	0.02	3	0.057	0.2	0.18	<0.02	11
NQ15/00983	13/03/2015		43	<0.05	<0.01	0.14	0.49	0.013	1.9	0.034	0.097	0.25	<0.02	11
NQ15/00984	13/03/2015		<0.5	<0.05	<0.01	<0.05	0.51	<0.01	1.4	0.027	<0.01	0.077	<0.02	41
NQ15/00985	13/03/2015		0.8	<0.05	<0.01	<0.05	0.47	<0.01	0.66	0.028	<0.01	0.12	<0.02	32
NQ15/00986	13/03/2015		0.79	<0.05	<0.01	<0.05	0.45	<0.01	0.98	0.033	<0.01	0.12	<0.02	33
NQ15/00987	13/03/2015		0.75	<0.05	<0.01	<0.05	0.38	<0.01	0.78	0.039	<0.01	0.13	<0.02	41
NQ15/00988	13/03/2015		1.6	<0.05	<0.01	<0.05	0.42	<0.01	2	0.1	<0.01	0.079	<0.02	31
NQ15/00989	14/03/2015		<0.5	<0.05	<0.01	<0.05	0.72	<0.01	0.27	0.034	<0.01	0.22	<0.02	11
NQ15/00990	14/03/2015		<0.5	<0.05	<0.01	<0.05	0.47	<0.01	0.3	0.03	<0.01	0.25	<0.02	8.3
NQ15/00991	14/03/2015		<0.5	<0.05	<0.01	<0.05	0.43	<0.01	0.37	0.034	<0.01	0.19	<0.02	9.2
NQ15/00992	14/03/2015		<0.5	<0.05	<0.01	<0.05	0.64	<0.01	1.1	0.027	<0.01	0.25	<0.02	11
NQ15/00993	14/03/2015		<0.5	<0.05	<0.01	<0.05	0.62	<0.01	1.5	0.026	<0.01	0.017	<0.02	20
NQ15/00994	15/03/2015		<0.5	<0.05	<0.01	<0.05	0.37	<0.01	0.23	0.075	<0.01	0.62	<0.02	12
NQ15/00995	15/03/2015		14	<0.05	<0.01	<0.05	0.37	0.011	1.6	0.069	0.02	0.7	<0.02	15
NQ15/00996	15/03/2015		21	0.076	<0.01	<0.05	0.39	0.021	3.3	0.13	0.032	0.41	<0.02	15
NQ15/00997	15/03/2015		1.8	<0.05	<0.01	<0.05	0.38	<0.01	0.33	0.12	0.14	0.43	<0.02	13
NQ15/00998	15/03/2015		1.3	<0.05	<0.01	<0.05	0.37	0.019	0.45	0.23	<0.01	0.89	<0.02	12
NQ15/00999	15/03/2015	prawn head	29	0.23	0.14	0.29	82	0.06	7.8	0.035	0.091	0.29	0.14	21
NQ15/01000	15/03/2015	prawn tail	6.2	0.18	<0.01	0.072	9.4	0.017	3.3	<0.01	0.019	0.16	<0.02	13
NQ15/01001	15/03/2015	prawn head	71	0.18	0.13	0.24	33	0.084	41	<0.01	0.13	0.41	0.12	31
NQ15/01002	15/03/2015	prawn tail	16	0.078	<0.01	0.059	17	0.036	13	<0.01	0.037	0.39	0.063	18
NQ15/01003	15/03/2015	prawn head	200	0.76	0.16	0.48	67	0.25	28	0.047	0.38	0.39	0.37	32
NQ15/01004	15/03/2015	prawn tail	18	0.19	<0.01	0.082	17	0.038	8.1	<0.01	0.045	0.3	0.03	16
NQ15/01005	15/03/2015	prawn head	130	0.42	0.096	0.34	39	0.25	100	0.017	0.3	0.43	0.16	57
NQ15/01006	15/03/2015	prawn tail	21	0.15	<0.01	0.074	14	0.033	15	<0.01	0.082	0.3	0.044	15
NQ15/01007	15/03/2015	prawn head	47	0.23	0.22	0.2	54	0.1	23	0.057	0.14	0.36	0.49	64
NQ15/01008	15/03/2015	prawn tail	9.5	0.14	<0.01	0.082	14	0.024	11	0.019	0.037	0.26	0.077	16
NQ15/01009	15/03/2015		<0.5	<0.05	<0.01	<0.05	0.3	0.13	3	0.05	<0.01	0.24	<0.02	23
NQ15/01010	15/03/2015		2.5	<0.05	0.014	0.072	0.49	<0.01	3.4	0.032	<0.01	0.33	<0.02	20
NQ15/01011	15/03/2015		1.4	0.053	<0.01	<0.05	0.25	0.019	7.7	0.048	<0.01	0.18	<0.02	24
NQ15/01012	15/03/2015		2.8	0.057	<0.01	<0.05	0.55	0.012	5.9	0.028	<0.01	0.3	<0.02	27
NQ15/01013	15/03/2015		1.4	<0.05	<0.01	<0.05	0.29	<0.01	2.6	0.051	<0.01	0.35	<0.02	21
NQ15/01014	15/03/2015		6.4	<0.05	<0.01	<0.05	0.57	0.019	3.4	0.037	<0.01	0.29	<0.02	51
NQ15/01015	15/03/2015		3.7	<0.05	<0.01	<0.05	0.57	0.065	2	0.054	<0.01	0.27	<0.02	39
NQ15/01016	15/03/2015		4.2	<0.05	<0.01	<0.05	0.56	0.023	3.3	0.036	0.013	0.29	<0.02	42
NQ15/01017	15/03/2015		2.8	<0.05	<0.01	<0.05	0.52	0.021	3.3	0.04	<0.01	0.33	<0.02	42
NQ15/01018	15/03/2015		3.5	<0.05	<0.01	<0.05	0.61	0.027	6.6	0.042	<0.01	0.28	<0.02	56
NQ15/01019	16/03/2015		<0.5	<0.05	0.012	<0.05	0.44	0.017	1	0.039	0.011	0.3	<0.02	19
NQ15/01020	16/03/2015		2.6	<0.05	<0.01	<0.05	0.45	0.026	1.9	0.029	0.011	0.28	<0.02	23
NQ15/01021	16/03/2015		1.5	<0.05	<0.01	<0.05	0.49	0.062	2.4	0.022	0.012	0.27	<0.02	23
NQ15/01022	16/03/2015		77	0.23	0.014	0.12	0.73	0.16	6.8	0.031	0.11	0.29	<0.02	27
NQ15/01023	17/03/2015		9.9	0.096	0.019	<0.05	0.55	0.42	3.2	0.028	0.022	0.31	<0.02	27
NQ15/01024	17/03/2015		2.3	<0.05	<0.01	<0.05	0.36	<0.01	1.6	0.23	<0.01	0.68	<0.02	14
NQ15/01025	17/03/2015		9.7	<0.05	0.011	<0.05	0.65	0.013	1.6	0.09	0.02	0.69	<0.02	15
NQ15/01026	17/03/2015		4.4	<0.05	<0.01	<0.05	0.57	<0.01	2.5	0.083	0.015	0.2	<0.02	13
NQ15/01027	17/03/2015		23	0.14	<0.01	<0.05	0.75	0.041	9.5	0.085	0.042	0.24	<0.02	24
NQ15/01028	17/03/2015		3.7	<0.05	<0.01	<0.05	0.4	<0.01	1.9	0.15	<0.01	0.41	<0.02	15
NQ15/01029	17/03/2015		4.1	0.45	<0.01	0.061	0.24	0.023	2.9	0.033	0.012	0.082	<0.02	10
NQ15/01030	17/03/2015		11	1.3	<0.01	0.11	0.39	0.024	4.2	0.037	0.041	0.11	<0.02	10
NQ15/01031	17/03/2015		5.2	0.23	<0.01	<0.05	0.25	<0.01	1.8	0.015	0.019	0.91	<0.02	8.6
NQ15/01032	17/03/2015		0.58	0.78	<0.01	<0.05	0.27	<0.01	0.36	0.017	0.017	0.077	<0.02	5.2
NQ15/01033	17/03/2015		1.3	0.079	<0.01	<0.05	0.11	<0.01	0.19	0.013	<0.01	0.11	<0.02	3

Source:
BMT WBM Golpu Project ESIA Aquatic Ecology Assessment, Downstream Impact Assessment and Sediment Transport Assessment (BMT WBN 2015)
Appendix D Fish Tissue Analysis
Government National Measurement Institute Report #RN1063560

Table H
Nearshore Marine Water Data - Baseline

Dissolved metals results at 1.5 m depth

Date	Location	Metal	Aluminium	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Tin	Zinc
		PNG criteriaa	-	50	1,000	2,000	1	10	LODc	30	1,000	4	2,000	0.2	1,000	10	5	500	5,000
		ANZECC 2000b	-	-	-	-	0.7	27.4	1	1.3	-	4.4	-	0.1	7	-	1.4	-	15
Date	**Location**																		
Nov-16	R1		<5	1.2	12	**3,580**	<0.2	<0.5	<0.2	<1	<5	<0.2	4	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	R2		<5	1.2	25	**3,030**	<0.2	<0.5	<0.2	<1	<5	<0.2	8.5	<0.1	<0.5	2	<0.1	<5	<5
Nov-16	L1		<5	2.2	28	**2,160**	<0.2	<0.5	<0.2	1	<5	<0.2	10.2	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	L3		<5	0.8	19	1,310	<0.2	<0.5	<0.2	<1	42	<0.2	40.9	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	L4		<5	1.2	20	1,660	<0.2	<0.5	<0.2	<1	49	<0.2	53.2	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	M1		16	1.8	31	**2,230**	<0.1	<0.5	0.2	1	<5	<0.2	1.5	<0.1	0.6	<2	<0.1	<5	<5
Nov-16	M2		21	2.4	43	**2,560**	<0.1	<0.5	<0.2	1	<5	<0.2	7	<0.1	0.6	<2	<0.1	<5	<5
Nov-16	V1		71	1.5	25	**2,540**	<0.1	<0.5	<0.2	2	21	<0.2	10.8	<0.1	0.7	<2	<0.1	<5	<5
Nov-16	LA1d		18	1.4	17	**3,380**	<0.1	<0.5	<0.2	<1	<5	<0.2	4.8	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	W1		5	1.2	31	**2,500**	<0.2	<0.5	0.2	1	<5	<0.2	13.2	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	W2		5	1.3	31	**2,600**	<0.2	<0.5	<0.2	<1	<5	<0.2	11.8	<0.1	<0.5	<2	<0.1	<5	<5
Nov-16	B1		14	1.4	28	**3,380**	<0.2	<0.5	<0.2	1	<5	<0.2	16.4	<0.1	<0.5	2	<0.1	<5	<5
Nov-16	S1		10	1.2	9	**3,850**	<0.1	<0.5	<0.2	<1	<5	<0.2	1.3	<0.1	<0.5	<2	<0.1	<5	<5
Feb-17	LA1		8	1.3	8	**3,930**	<0.1	<0.5	<0.2	<1	23	<0.2	5.5	<0.0001	<0.5	4	<0.1	<5	<5
Feb-17	LA2		9	1.4	8	**3,970**	<0.1	<0.5	<0.2	<1	<5	<0.2	3.3	<0.0001	1.6	4	<0.1	<5	<5
Feb-17	LA3		12	1.6	8	**3,940**	<0.1	<0.5	<0.2	<1	<5	<0.2	2.8	<0.0001	2.3	5	<0.1	<5	<5
Feb-17	LA4		16	1.4	11	**3,730**	<0.1	<0.5	<0.2	<1	<5	<0.2	7	<0.0001	1.4	5	<0.1	<5	<5
Feb-17	LA5		14	1.5	10	**3,860**	<0.1	<0.5	<0.2	<1	<5	0.4	3.1	<0.0001	0.5	7	<0.1	<5	<5
Feb-17	M1		10	4.1	26.1	276	<0.05	0.2	<0.1	1.9	10	<0.1	0.8	<0.0001	0.8	0.9	0.4	<0.2	<1
Feb-17	V1		14	1.4	9	**3,910**	<0.1	<0.5	<0.2	<1	<5	<0.2	7.6	<0.0001	0.6	5	<0.1	<5	<5
Feb-17	W1		11	1.4	11	**3,830**	<0.1	<0.5	<0.2	<1	<5	<0.2	6.6	<0.0001	<0.5	4	<0.1	<5	<5
Feb-17	W2		13	1.4	12	**3,920**	<0.1	<0.5	<0.2	<1	<5	<0.2	7.2	<0.0001	<0.5	4	<0.1	<5	<5
Feb-17	B1		9	1.3	7	**3,850**	<0.1	0.6	<0.2	<1	<5	<0.2	21.2	<0.0001	<0.5	5	<0.1	<5	<5
Feb-17	S2		<5	1.5	4	**4,150**	<0.1	<0.5	<0.2	<1	<5	<0.2	<0.5	<0.0001	<0.5	7	<0.1	<5	<5

Note: All units are in µg/L
Exceedance of PNG criteria is shown in bold. Exceedance of ANZECC/ARMCANZ (2000) guidelines are shown in grey highlight.
Source: Environment (Water Quality Criteria) Regulation 2002 - Schedule 1 Water Quality Criteria for Aquatic Life Protection.
Source: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).
PNG criterion for cobalt is the laboratory limit of detectability (LOD).

Table I
Marine Biota Data - Baseline
Deep Slope and Lae Market

Concentrations of elements (mg/kg) in liver and muscle samples of speciments caught in the upper Huon Gulf (n=40) and sourced from the Lae street market (n=14) in November 2016 and May 2017 (n=20)

		Arsenic (PQL = 0.4)										Cadmium (PQL = 0.05)										Chromium (PQL = 0.1)									
		Muscle					Liver					Muscle					Liver					Muscle					Liver				
Date	Caught species	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev
Nov-16	Dwarf gulper shark	**6.9**	**36**	**16.4**	33	6.16	1.2	**20**	**9.3**	33	4.5	<0.05	0.07	0.07	33	0.01	0.31	10	2.88	33	2.56	<0.1	0.19	0.19	33	0	<0.1	0.23	0.15	33	0.07
	Longfin gulper shark	**12**	**34**	**22**	3	11.14	**10**	**16**	**12.3**	3	3.2	<0.05	0.15	0.15	3	0	14	23	19	3	4.58	<0.1	<0.1	<0.1	3	0	<0.1	<0.1	<0.1	3	0
	Blackspotted croaker	0.96	0.96	0.96	1	0	4	**4**	**4**	1	0	<0.05	<0.05	<0.05	1	0	4.5	4.5	4.5	1	0	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Gulper shark	**33**	**33**	**33**	1	0	**5.9**	**5.9**	**5.9**	1	0	<0.05	<0.05	<0.05	1	0	12	12	12	1	0	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Mangrove jack	<0.4	<0.4	<0.4	1	0	1.3	1.3	1.3	1	0	<0.05	<0.05	<0.05	1	0	7.8	7.8	7.8	1	0	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Saddletail snapper	**2.8**	**2.8**	**2.8**	1	0	**19**	**19**	**19**	1	0	<0.05	<0.05	<0.05	1	0	2.3	2.3	2.3	1	0	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Market species																														
	Mangrove jack	0.41	**2.6**	1.51	2	1.55	1.3	**4.2**	**2.75**	2	2.05	<0.05	<0.05	<0.05	2	0	0.16	0.36	0.26	2	0.14	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Saddletail snapper	**2.3**	**6.2**	**4.34**	5	1.6	**3.5**	**16**	**10.9**	5	4.67	<0.05	<0.05	<0.05	5	0	1.4	2.8	2	5	0.52	<0.1	<0.1	<0.1	5	0	<0.1	<0.1	<0.1	5	0
	Sharptooth jobfish	0.83	1.8	1.32	2	0.69	**2.6**	**4.4**	**3.5**	2	1.27	<0.05	<0.05	<0.05	2	0	5.5	6.3	5.9	2	0.57	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Bigeye trevally	<0.4	0.6	0.52	4	0.1	0.71	**2.4**	1.45	4	0.7	<0.05	<0.05	<0.05	4	0	0.74	2.8	1.99	4	0.94	<0.1	<0.1	<0.1	4	0	<0.1	<0.1	<0.1	4	0
	Pennantfish	**5**	**5**	**5**	1	0	**7.7**	**7.7**	**7.7**	1	0	<0.05	<0.05	<0.05	1	0	1.3	1.3	1.3	1	0	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
May-17	**Caught species**																														
	Dwarf gulper shark	**8.9**	**30**	**15.65**	11	6.35	-	-	-	-	-	<0.05	<0.05	<0.05	11	0	-	-	-	-	-	<0.1	0.19	0.15	11	0.03	-	-	-	-	-
	Longfin gulper shark	**16**	**38**	**27**	2	15.56	-	-	-	-	-	<0.05	<0.05	<0.05	2	0	-	-	-	-	-	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	**5.5**	**21**	**13.26**	5	6.22	-	-	-	-	-	<0.05	<0.05	<0.05	5	0	-	-	-	-	-	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	**3.7**	**3.7**	**3.7**	1	0	-	-	-	-	-	<0.05	<0.05	<0.05	1	0	-	-	-	-	-	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	**32**	**32**	**32**	1	0	-	-	-	-	-	<0.05	<0.05	<0.05	1	0	-	-	-	-	-	<0.1	<0.1	<0.1	1	0	-	-	-	-	-

		Copper (PQL = 0.05)														Lead (PQL = 0.1)									
		Muscle							Liver							Muscle					Liver				
Date	Caught species	Min	Median	Max	Mean	n	StdDev	90th Perc.	Min	Median	Max	Mean	n	StdDev	90th Perc.	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev
Nov-16	Dwarf gulper shark	0.12	0.18	2.4	0.27	33	0.39	0	0.06	1.4	3.9	1.54	33	0.77	2.4	<0.1	<0.1	<0.1	33	0	<0.1	<0.1	<0.1	33	0
	Longfin gulper shark	0.16	0.25	0.31	0.24	3	0.08	0.3	1.2	1.7	2.7	1.87	3	0.76	2.5	<0.1	<0.1	<0.1	3	0	<0.1	<0.1	<0.1	3	0
	Blackspotted croaker	0.13	0.13	0.13	0.13	1	0	0.13	20	20	20	20	1	0	20	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Gulper shark	0.11	0.11	0.11	0.11	1	0	0.11	5	5	5	5	1	0	5	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Mangrove jack	0.13	0.13	0.13	0.13	1	0	0.13	25	25	25	25	1	0	25	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Saddletail snapper	0.11	0.11	0.11	0.11	1	0	0.11	6.4	6.4	6.4	6.4	1	0	6.4	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
	Market species																								
	Mangrove jack	0.11	0.12	0.12	0.12	2	0.01	0.12	6.6	11.8	17	11.8	2	7.35	15.96	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Saddletail snapper	0.08	0.1	0.14	0.1	5	0.02	0.12	1.8	2.7	4.7	2.92	5	1.07	3.94	<0.1	<0.1	<0.1	5	0	<0.1	<0.1	<0.1	5	0
	Sharptooth jobfish	0.11	0.14	0.16	0.14	2	0.04	0.16	4.3	4.7	5.1	4.7	2	0.57	5.02	<0.1	<0.1	<0.1	2	0	<0.1	<0.1	<0.1	2	0
	Bigeye trevally	0.29	0.5	0.66	0.49	4	0.17	0.64	2.6	4.3	5.7	4.23	4	1.65	5.67	<0.1	<0.1	<0.1	4	0	<0.1	<0.1	<0.1	4	0
	Pennantfish	0.19	0.19	0.19	0.19	1	0	0.19	2.7	2.7	2.7	2.7	1	0	2.7	<0.1	<0.1	<0.1	1	0	<0.1	<0.1	<0.1	1	0
May-17	**Caught species**																								
	Dwarf gulper shark	0.07	0.1	0.12	0.1	11	0.02	0.12	-	-	-	-	-	-	-	<0.1	0.1	0.1	11	0	-	-	-	-	-
	Longfin gulper shark	0.09	0.11	0.14	0.11	2	0.04	0.13	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	2	0	-	-	-	-	-
	Fatspine spurdog	0.11	0.16	0.17	0.15	5	0.03	0.17	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	5	0	-	-	-	-	-
	Saddletail snapper	0.09	0.09	0.09	0.09	1	0	0.09	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	1	0	-	-	-	-	-
	Common pike eel	0.1	0.1	0.1	0.1	1	0	0.1	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	1	0	-	-	-	-	-

		Mercury (PQL = 0.1)														Manganese (PQL = 0.1)										Nickel (PQL = 0.06)									
		Muscle							Liver							Muscle					Liver					Muscle					Liver				
Date	Caught species	Min	Median	Max	Mean	n	StdDev	90th Perc	Min	Median	Max	Mean	n	StdDev	90th Perc	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev	Min	Max	Mean	n	StdDev
Nov-16	Dwarf gulper shark	0.02	0.71	**2.2**	0.75	33	0.49	1.38	0.02	0.05	**4.4**	0.31	33	0.82	0.67	<0.1	0.14	0.11	33	0.01	<0.1	0.59	0.38	33	0.14	<0.06	0.07	0.07	33	0	<0.06	0.14	0.09	33	0.03
	Longfin gulper shark	0.99	1.1	**1.3**	**1.13**	3	0.16	1.26	0.03	0.05	0.05	0.04	3	0.01	0.05	0.1	0.11	0.11	3	0.01	0.11	0.31	0.22	3	0.1	<0.06	<0.06	<0.06	3	0	<0.06	<0.06	<0.06	3	0
	Blackspotted croaker	0.26	0.26	0.26	0.26	1	0	0.26	0.34	0.34	0.34	0.34	1	0	0.34	<0.1	<0.1	<0.1	1	0	0.57	0.57	0.57	1	0	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Gulper shark	1.5	1.5	**1.5**	**1.5**	1	0	1.5	0.67	0.67	0.67	0.67	1	0	0.67	<0.1	<0.1	<0.1	1	0	0.18	0.18	0.18	1	0	<0.06	<0.06	<0.06	1	0	0.07	0.07	0.07	1	0
	Mangrove jack	0.53	0.53	0.53	**0.53**	1	0	0.53	14	14	**14**	**14**	1	0	14	<0.1	<0.1	<0.1	1	0	1	1	1	1	0	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Saddletail snapper	0.05	0.05	0.05	0.05	1	0	0.05	0.03	0.03	0.03	0.03	1	0	0.03	<0.1	<0.1	<0.1	1	0	1.56	1.56	1.56	1	0	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
	Market species																																		
	Mangrove jack	0.03	0.04	0.05	0.04	2	0.01	0.05	0.16	0.44	0.72	0.44	2	0.4	0.66	<0.1	<0.1	<0.1	2	0	1.16	2.21	1.69	2	0.74	<0.06	<0.06	<0.06	2	0	<0.06	<0.06	<0.06	2	0
	Saddletail snapper	0.19	0.21	0.36	0.24	5	0.07	0.31	0.4	0.93	**1.9**	**1.02**	5	0.54	1.52	<0.1	0.1	0.1	5	0	0.93	1.31	1.04	5	0.16	<0.06	<0.06	<0.06	5	0	<0.06	0.06	0.06	5	0
	Sharptooth jobfish	0.05	0.2	0.35	0.2	2	0.21	0.32	0.4	0.85	**1.3**	**0.85**	2	0.64	1.21	<0.1	<0.1	<0.1	2	0	1.74	2.41	2.08	2	0.47	<0.06	<0.06	<0.06	2	0	<0.06	<0.06	<0.06	2	0
	Bigeye trevally	0.34	0.51	0.71	**0.52**	4	0.16	0.67	0.73	1.4	**2**	**1.38**	4	0.66	1.97	<0.1	0.11	0.11	4	0	1.29	1.62	1.44	4	0.16	<0.06	<0.06	<0.06	4	0	<0.06	<0.06	<0.06	4	0
	Pennantfish	0.25	0.25	0.25	0.25	1	0	0.25	0.51	0.51	0.51	**0.51**	1	0	0.51	<0.1	<0.1	<0.1	1	0	1.32	1.32	1.32	1	0	<0.06	<0.06	<0.06	1	0	<0.06	<0.06	<0.06	1	0
May-17	**Caught species**																																		
	Dwarf gulper shark	0.14	0.35	1.1	0.48	11	0.34	0.99	-	-	-	-	-	-	-	<0.1	0.18	0.12	11	0.03	-	-	-	-	-	<0.06	<0.06	<0.06	11	0	-	-	-	-	-
	Longfin gulper shark	0.35	0.66	0.97	0.66	2	0.44	0.91	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	2	0	-	-	-	-	-	<0.06	<0.06	<0.06	2	0	-	-	-	-	-
	Fatspine spurdog	0.08	0.38	0.75	0.41	5	0.33	0.75	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	5	0	-	-	-	-	-	<0.06	<0.06	<0.06	5	0	-	-	-	-	-
	Saddletail snapper	0.06	0.06	0.06	0.06	1	0	0.06	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	1	0	-	-	-	-	-	<0.06	<0.06	<0.06	1	0	-	-	-	-	-
	Common pike eel	0.24	0.24	0.24	0.24	1	0	0.24	-	-	-	-	-	-	-	0.12	0.12	0.12	1	0	-	-	-	-	-	<0.06	<0.06	<0.06	1	0	-	-	-	-	-

		Selenium (PQL = 0.5)														Selenium (PQL = 0.5)													
		Muscle							Liver							Muscle							Liver						
Date	Caught species	Min	Median	Max	Mean	n	StdDev	90th Perc	Min	Median	Max	Mean	n	StdDev	90th Perc	Min	Median	Max	Mean	n	StdDev	90th Perc	Min	Median	Max	Mean	n	StdDev	90th Perc
Nov-16	Dwarf gulper shark	<0.5	**0.58**	0.71	0.59	33	0.06	0.65	<0.5	**0.9**	1.5	0.92	33	0.25	1.26	2.1	2.6	3.7	2.65	33	0.32	2.98	0.63	**8.4**	22	8.72	33	3.81	12
	Longfin gulper shark	<0.5	**0.57**	0.63	0.57	3	0.08	0.62	0.62	**0.65**	1.6	0.96	3	0.56	1.41	2.3	2.6	2.7	2.53	3	0.21	2.68	14	**16**	22	17.33	3	4.16	**20.8**
	Blackspotted croaker	<0.5	0	<0.5	<0.5	1	0	0	4	**4**	4	4	1	0	**4**	2.2	2.2	2.2	2.2	1	0	2.2	45	**45**	45	45	1	0	**45**
	Gulper shark	0.67	**0.67**	0.67	0.67	1	0	0.67	1.7	**1.7**	1.7	1.7	1	0	1.7	3.3	3.3	3.3	3.3	1	0	3.3	15	**15**	15	15	1	0	**15**
	Mangrove jack	0.66	**0.66**	0.66	0.66	1	0	0.66	6.5	**6.5**	6.5	6.5	1	0	**6.5**	3.1	3.1	3.1	3.1	1	0	3.1	48	**48**	48	48	1	0	**48**
	Saddletail snapper	<0.5	0	<0.5	<0.5	1	0	0	2.7	**2.7**	2.7	2.7	1	0	**2.7**	2.2	2.2	2.2	2.2	1	0	2.2	48	**48**	48	48	1	0	**48**
	Market species																												
	Mangrove jack	0.5	**0.52**	0.53	0.52	2	0.02	0.53	1.3	**2**	2.7	2	2	0.99	**2.56**	2.6	2.7	2.8	2.7	2	0.14	2.78	34	**44.5**	55	44.5	2	14.85	**52.9**
	Saddletail snapper	<0.5	0	<0.5	<0.5	5	0	0	1.7	**2**	2.8	2.08	5	0.43	**2.52**	2.2	2.5	3.4	2.6	5	0.47	3.08	22	**32**	48	33.4	5	9.63	**43.2**
	Sharptooth jobfish	<0.5	0	<0.5	<0.5	2	0	0	2.2	**3.2**	4.2	3.2	2	1.41	**4**	2.4	2.45	2.5	2.45	2	0.07	2.49	49	**53.5**	58	53.5	2	6.36	**57.1**
	Bigeye trevally	0.67	**0.8**	1.1	0.84	4	0.19	1.03	2.9	**2.95**	3.7	3.13	4	0.39	**3.49**	3.4	4.3	4.8	4.2	4	0.59	4.68	35	**40**	49	41	4	6.06	**46.9**
	Pennantfish	<0.5	0	<0.5	<0.5	1	0	0	2.8	**2.8**	2.8	2.8	1	0	**2.8**	3.1	3.1	3.1	3.1	1	0	3.1	35	**35**	35	35	1	0	**35**
May-17	**Caught species**																												
	Dwarf gulper shark	<0.5	**0.53**	0.56	0.53	11	0.03	0.55	-	-	-	-	-	-	-	1.9	2.1	2.4	2.13	11	0.16	2.3	-	-	-	-	-	-	-
	Longfin gulper shark	<0.5	**0.52**	0.52	0.52	2	0	0.52	-	-	-	-	-	-	-	2.1	2.4	2.7	2.4	2	0.42	2.64	-	-	-	-	-	-	-
	Fatspine spurdog	<0.5	**0.53**	0.53	0.53	5	0	0.53	-	-	-	-	-	-	-	2	2.4	2.5	2.34	5	0.21	2.5	-	-	-	-	-	-	-
	Saddletail snapper	<0.5	0	<0.5	<0.5	1	0	0	-	-	-	-	-	-	-	2.8	2.8	2.8	2.8	1	0	2.8	-	-	-	-	-	-	-
	Common pike eel	<0.5	0	<0.5	<0.5	1	0	0	-	-	-	-	-	-	-	2.6	2.6	2.6	2.6	1	0	2.6	-	-	-	-	-	-	-

Notes: Bold indicates exceedance of the FSANZ standard
- denotes no data
Grey shading indicates exceedance of the FSANZ GEL

Source: EIS Ch11 Deep Slope Fish Characterisation

Table J
Surface Water Data - Predicted: Modelled Wastewater Discharge

Reporting Locations – TSS and Dissolved Metals

Site	Watercourse	UTM x	UTM y	Description	Nickel [ug/L] Pre-Development Dry	Nickel Pre-Development Wet	Nickel Construction Dry	Nickel Construction Wet	Copper [ug/L] Pre-Development Dry	Copper Pre-Development Wet	Copper Construction Dry	Copper Construction Wet	Selenium [ug/L] Pre-Development Dry	Selenium Pre-Development Wet	Selenium Construction Dry	Selenium Construction Wet
CHA1	Chaunong Creek	439010	9256092	Downstream of Bavaga River confluence	0.6	1.6	0.6	1.6	0.7	2.7	0.7	2.7	5.3	5	5.3	5
CHA2	Chaunong Creek	438525	9253743	Upstream of Bavaga River confluence	0.6	1.6	0.7	1.6	0.7	2.7	0.7	2.7	5.1	5	5.1	5
CHA3	Chaunong Creek	437733	9251656	Downstream of Bobdul Creek confluence	0.7	1.6	0.7	1.6	0.8	2.8	0.8	2.8	5.2	5	5.2	5
CHA4	Chaunong Creek	436208	9249763	Upstream of Bobdul Creek confluence	0	1.6	0	1.6	0	2.8	0	2.8	0	5	0	5
CHA5	Chaunong Creek	435288	9247795	Downstream of Womul and Boganchong Creek confluence	0.6	1.6	0.6	1.6	0.7	2.8	0.7	2.8	5.2	5	5.2	5
CHA6	Chaunong Creek	435236	9245870	Upstream of Papas village	0.6	0.8	0.6	0.8	0.6	1	0.7	1	5	5	5.1	5
LWT1	Lower Watut River	448236	9262796	Downstream of Chiatz village downstream of Waime River confluence	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT2	Lower Watut River	443586	9261722	Downstream of Chiatz village	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT3	Lower Watut River	440789	9259402	Upstream of Ngarubuaring village	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT4	Lower Watut River	438209	9256469	Downstream of Chaunon village	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT5	Lower Watut River	435266	9251667	Downstream of Uruf and Kapunung village	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT6	Lower Watut River	432337	9249057	Downstream of Wongkins village	1.1	1.6	1.1	1.6	1.7	2.8	1.8	2.8	5	5	5	5
LWT7	Lower Watut River	432873	9244365	Adjacent to Wori village	1.1	1.6	1.1	1.6	1.7	2.8	1.7	2.8	5	5	5	5
LWT8	Lower Watut River	432964	9240538	Downstream of Madzim and Maralina villages	1.1	1.6	1.1	1.6	1.7	2.8	1.7	2.8	5	5	5	5
LWT9	Lower Watut River	435123	9238445	Downtream of Wafi River confluence	1.1	1.6	1.1	1.6	1.7	2.8	1.7	2.8	5	5	5	5
WAF1	Wafi River	435782	9238473	Upstream of Waut River confluence (downstream	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	5	5	5	5
WAF2	Wafi River	438628	9240794	Downstream of Nambonga village	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	5	5	5	5
WAF3	Wafi River	440208	9239523	Upstream of Venembele village	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	5	5	5	5
WAF4	Wafi River	441309	9241297	Downstream of Hekeng village	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	5	5	5	5
WML1	Womul Creek	435599	9245255	Upstream of Chaunong Creek confluence	0.6	0.7	0.5	0.7	0.6	0.9	0.6	0.8	5	5	5	5
BCH1	Boganchong Creek	435399	9245179	Upstream of Chaunong Creek confluence	0.6	0.7	0.6	0.7	0.6	0.9	0.6	0.8	5	5	5	5
BAV1	Bavaga River	440032	9253224	Downstream of proposed quarry												
BAV2	Bavaga River	441050	9249124	Upstream of proposed quarry												
BAV1a	Bavaga River	439575	9254040	Downstream of proposed quarry (inside model domain)	0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6	5	5	5	5
Note that results are not available for BAV1 and BAV2 as they are located outside of the model domain					1.6		1.6		2.8		2.8		5.3		5.3	

Site	Watercourse	UTM x	UTM y	Description	Arsenic [ug/L] Pre-Development Dry	Arsenic Pre-Development Wet	Arsenic Construction Dry	Arsenic Construction Wet	Zinc [ug/L] Pre-Development Dry	Zinc Pre-Development Wet	Zinc Construction Dry	Zinc Construction Wet	Manganese [ug/L] Pre-Development Dry	Manganese Pre-Development Wet	Manganese Construction Dry	Manganese Construction Wet
CHA1	Chaunong Creek	439010	9256092	Downstream of Bavaga River confluence	0.8	4.4	0.8	4.4	4.6	10.4	4.6	10.4	11.3	20.5	11.3	20.5
CHA2	Chaunong Creek	438525	9253743	Upstream of Bavaga River confluence	0.8	4.3	0.8	4.3	5.1	10.4	5.1	10.4	11.5	20.5	11.5	20.5
CHA3	Chaunong Creek	437733	9251656	Downstream of Bobdul Creek confluence	0.9	4.4	0.9	4.4	6.7	10.4	6.6	10.4	12.7	20.6	12.6	20.6
CHA4	Chaunong Creek	436208	9249763	Upstream of Bobdul Creek confluence	0	4.4	0	4.4	0	10.5	0	10.5	0	20.7	0	20.7
CHA5	Chaunong Creek	435288	9247795	Downstream of Womul and Boganchong Creek confluence	0.8	4.4	0.8	4.4	5	10.5	5	10.5	11.6	20.6	11.6	20.6
CHA6	Chaunong Creek	435236	9245870	Upstream of Papas village	0.7	1.1	0.7	1.2	4.4	7.7	4.7	8.5	10.8	13.2	11	13.5
LWT1	Lower Watut River	448236	9262796	Downstream of Chiatz village downstream of Waime River confluence	3.6	4.4	3.6	4.4	6.6	10.5	6.7	10.5	13.2	20.6	13.2	20.6
LWT2	Lower Watut River	443586	9261722	Downstream of Chiatz village	3.6	4.4	3.6	4.4	6.6	10.4	6.7	10.4	13.3	20.6	13.2	20.5
LWT3	Lower Watut River	440789	9259402	Upstream of Ngarubuaring village	3.6	4.4	3.6	4.4	6.7	10.5	6.7	10.5	13.3	20.6	13.3	20.6
LWT4	Lower Watut River	438209	9256469	Downstream of Chaunon village	3.6	4.4	3.6	4.4	6.7	10.5	6.8	10.5	13.3	20.6	13.4	20.7
LWT5	Lower Watut River	435266	9251667	Downstream of Uruf and Kapunung village	3.7	4.4	3.6	4.4	6.7	10.5	6.8	10.5	13.3	20.6	13.4	20.7
LWT6	Lower Watut River	432337	9249057	Downstream of Wongkins village	3.7	4.4	3.6	4.4	6.7	10.5	6.8	10.5	13.3	20.7	13.4	20.7
LWT7	Lower Watut River	432873	9244365	Adjacent to Wori village	3.7	4.4	3.7	4.4	6.7	10.5	6.7	10.5	13.3	20.7	13.3	20.7
LWT8	Lower Watut River	432964	9240538	Downstream of Madzim and Maralina villages	3.6	4.4	3.6	4.4	6.7	10.5	6.7	10.5	13.3	20.7	13.3	20.7
LWT9	Lower Watut River	435123	9238445	Downtream of Wafi River confluence	3.6	4.4	3.6	4.4	6.7	10.5	6.7	10.5	13.3	20.7	13.3	20.7
WAF1	Wafi River	435782	9238473	Upstream of Waut River confluence (downstream	0.5	0.6	0.5	0.6	2.8	3.6	2.8	3.6	9.7	10.1	9.7	10.1
WAF2	Wafi River	438628	9240794	Downstream of Nambonga village	0.5	0.6	0.5	0.6	2.8	3.6	2.8	3.6	9.7	10.1	9.7	10.1
WAF3	Wafi River	440208	9239523	Upstream of Venembele village	0.5	0.6	0.5	0.6	2.8	3.5	2.8	3.5	9.7	10.1	9.7	10.1
WAF4	Wafi River	441309	9241297	Downstream of Hekeng village	0.5	0.6	0.5	0.6	2.6	3.3	2.6	3.3	9.5	10	9.5	10
WML1	Womul Creek	435599	9245255	Upstream of Chaunong Creek confluence	0.7	1	0.6	0.9	4.3	7.5	3.4	6.8	10.6	12.4	10	11.8
BCH1	Boganchong Creek	435399	9245179	Upstream of Chaunong Creek confluence	0.7	1	0.6	0.9	4.2	7.4	3.6	6.8	10.6	12.4	10.2	12
BAV1	Bavaga River	440032	9253224	Downstream of proposed quarry												
BAV2	Bavaga River	441050	9249124	Upstream of proposed quarry												
BAV1a	Bavaga River	439575	9254040	Downstream of proposed quarry (inside model domain)	0.5	0.6	0.5	0.6	2.6	3.9	2.6	3.9	9.6	10.3	9.6	10.3
Note that results are not available for BAV1 and BAV2 as they are located outside of the model domain					4.4		4.4		10.5		10.5		20.7		20.7	

Appendix C Summary Data of Model Outputs
This appendix contains summary data of model outputs (10th, 50th, and 95th percentile values) for
flow, TSS and dissolved metals extracted from the model at the various reporting locations

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Appendix C - Project Infrastructure and Facilities

<table>
<tr><td colspan="2">Project Infrastructure and Facilities</td></tr>
<tr><td colspan="2">Mine Area</td></tr>
<tr><td colspan="2">Block cave mine, declines and subsidence zone</td></tr>
<tr><td>Watut Declines Portal Terrace including:
• Decline entrances (portals)
• Watut Waste Rock Dump
• Water treatment facilities
• Ventilation fans
• Refrigeration plant including cooling towers
• Conveyors and transfer points
• Electrical substations and switch rooms
• Drainage and stormwater infrastructure
• Diesel generators and associated infrastructure
• Concrete batch plant
• Workshops, buildings, fuel facilities, washdown bay
• First aid and emergency response</td><td>Process plant terrace including:
• Watut Process Plant including:
o Feed conveyor
o Coarse ore stockpile
o Grinding units
o Flotation units
o Reagent storage
o Concentrate storage tanks and pump station
o Tailings thickeners, tanks and pump station
• Concrete batch plant
• Helicopter pad
• Offices
• Access control (security)
• Change house
• Mine power supply yard
• Laboratory
• Sewage treatment facility
• Workshop, fuel facilities and washdown bay
• Raw water dam
• Sedimentation dams
• Ore stockpiles</td></tr>
<tr><td>Nambonga Decline Portal Terrace including:
• Decline entrance (portal)
• Ventilation fans
• Air cooling system including refrigeration machines
• Transfer points for waste rock
• Drainage and stormwater infrastructure
• Diesel generators and associated infrastructure</td><td>Associated Nambonga Decline infrastructure and facilities:
• Miapilli Waste Rock Dump
• Miapilli Clay Borrow Pit
• Nambonga Haul Road
• Lower Papas Aggregate Source and crushing / screening area
• Concrete batch plant
• Process water tank
• Water treatment plant
• Workshops, buildings, fuel facilities, first aid, washdown bay
• Explosives magazine</td></tr>
<tr><td colspan="2">Ventilation shaft</td></tr>
<tr><td colspan="2">Wastewater discharge pipeline to the Watut River</td></tr>
<tr><td colspan="2">Raw water make-up pipeline from the Watut River to the Watut Process Plant (co-located with the wastewater discharge pipeline)</td></tr>
<tr><td colspan="2">Accommodation facilities (Fere Accommodation Facility, Finchif Construction Accommodation Facility)</td></tr>
<tr><td colspan="2">Power generation facilities (as required)</td></tr>
<tr><td colspan="2">Explosives magazines</td></tr>
<tr><td colspan="2">Waste management facility (including topsoil stockpiles/laydown areas)</td></tr>
<tr><td colspan="2">Borrow pits and gravel extraction sources:
• Migiki Borrow Pit
• Humphries Borrow Pit
• Northern Access Road borrow pits
• Bavaga River gravel extraction
• Waime River gravel extraction</td></tr>
<tr><td colspan="2">Mt Beamena Quarry, spoil and laydown and crushing/screening area</td></tr>
</table>

Project Infrastructure and Facilities
Mt Beamena Quarry Access Road
Infrastructure Corridor
Mine Access Road
Northern Access Road
Concentrate pipeline to transport the copper-gold concentrate from the Watut Process Plant to the concentrate filtration plant at the Port of Lae
Fuel pipeline from the Port of Lae to the power generation facilities (as required) at the Mine Area
Terrestrial tailings pipeline from the Mine Area to the Outfall Area
Construction pads and laydown areas
Coastal Area
Port Facilities Area including concentrate filtration plant and materials handling, water treatment plant and filtrate discharge pipeline, concentrate storage and ship loading facilities
Outfall System including mix/de-aeration tank, seawater intake pipelines, DSTP outfall pipelines, laydown area, diesel storage, parking and associated access road
Bulk intermediate fuel oil storage facility and fuel pump station at the Port of Lae
Laydown area for Outfall System construction (Lae Tidal Basin preferred)

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Appendix D - Toxicity Profiles

Arsenic

There are many different forms of organic and inorganic arsenic that occur in the environment, both naturally occurring and from human sources. Inorganic arsenic compounds are formed when arsenic combines with oxygen, chlorine and sulphur. Organic arsenic compounds are formed in plants and animals when arsenic is combined with hydrogen and carbon. Most compounds are white powders that have no odour, no taste and are not volatile (ATSDR, 2007). Arsenic is generally found in the form of arsenate (pentavalent arsenic) in oxygenated water. However, in reducing conditions it predominantly consists of arsenite (trivalent arsenic (WHO, 2001). In oxygenated soil, the pentavalent form of arsenic is more prevalent and in reducing conditions the trivalent form is dominant (WHO, 2001).

Arsenic compounds in food are generally in organic form and are considered to be relatively less toxic compared to inorganic arsenic compounds (FSANZ, 2013). Inorganic arsenic is found in relatively lower proportions which can vary depending on the type of food. Fish and other seafood often contain high levels of arsenic however it is most present in the form of non- or low-toxicity organo-arsenicals including arsenobetaine and arsenosugars (ATSDR, 2007a). Contributions of inorganic arsenic intake in the Asian diet is primarily from the dietary staples seafood (in high fish-consuming groups), cereal grains, particularly rice and consumption of drinking water. Between 50% and 70% of the total arsenic in rice is present as inorganic arsenic species (US FDA, 2016).

International seafood safety risk assessment agencies and researchers adopt 10% of total arsenic to representative of the inorganic arsenic species as this is considered to be a conservative approach given reviews of arsenic in fish tissue speciation studies indicate inorganic arsenic of between 1% and 5% are found in marine fish.

Toxicological Effects

Humans are mainly exposed to arsenic through food, water and inhalation of particulate matter in air. Arsenic is not readily absorbed through the skin. Once it enters the body both trivalent and pentavalent forms of arsenic are rapidly absorbed into the gastrointestinal tract (WHO, 2001). Inorganic arsenic can then be methylated and excreted from the body in the urine, however the extent to which this occurs can differ greatly depending on the individual (WHO, 2001).

Ingestion of large doses of arsenic will lead to acute effects including gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions, and eventually death. If death does not occur, other symptoms may include, bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy (WHO, 2001).

Chronic exposure to arsenic in drinking water has been shown to increase the risk of cancer in the skin, lungs, bladder and kidney, and other skin changes such as hyperkeratosis and changes to pigmentation (WHO, 2001). Arsenic is not volatile although occupational studies have demonstrated that exposure to airborne arsenic is causally related to cancer of the lung, based copper smelter studies (ATSDR, 2007a) (WHO, 2001).

Although it is noted that skin cancer is considered to be a result of exposure to arsenic, dermal absorption is generally considered to be negligible (NEPM, 2013). The oral bioavailability of arsenic varies depending on the form and media.

The JECFA noted that organic arsenic intakes of about 50 µg/kg bw/day (ie 3000 – 3500 µg/day for adults) produced no reports of ill effects,and that organoarsenicals found in fish, although almost completely absorbed, were rapidly excreted, unchanged, by humans.

Cancer Classification

IARC has classified arsenic as Group 1 (carcinogenic to humans). The USEPA has classified arsenic as Class A (human carcinogen).

Despite being identified as a carcinogen, it is considered a weak genotoxicity as epidemiological data and mechanistic information indicate that arsenic exhibits threshold behaviour. Arsenic has therefore been assessed using a threshold toxicity value.

Adopted Toxicity Criteria and Screening Levels

In 1983, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) estimated a provisional tolerable daily intake (PTWI) of 15µg/kg/week (WHO, 1983), based on a lowest observed adverse effect level (LOAEL) from a Canadian drinking water study. At its seventy-second meeting in 2010, JECFA determined that the inorganic arsenic lower limit on the benchmark dose for a 0.5% increased incidence of lung cancer in epidemiological studies was 3.0 µg/kg bw/day (2-7 µg/kg bw/day based on the range of estimated total dietary exposure). As the $BMDL_{0.5}$ was in the region of the PTWI (15 µg/kg bw), the PTWI was no longer considered appropriate and was withdrawn (WHO, 2010).

RIVM (2001) derived a tolerable daily intake (TDI) for arsenic of 0.001 mg/kg/day. The TDI was based on the JECFA PTWI of 15µg/kg/week, including an additional uncertainty factor of 2, to account for 'observational errors that are inevitable in epidemiological studies'. RIVM (2001) also derived an inhalation toxicity criteria of 0.001 mg/m^3.

Currently the Codex Alimentarius Commission (WHO, 2011) and the European Union currently have not established a standard for inorganic arsenic in seafood. Food Standards Australia New Zealand has a standard for inorganic arsenic levels in fish and crustaceans of 2 mg/kg ww. (FSANZ, 2013).

A review of international approaches to arsenic during the development of the Australian NEPM (2013) concluded a toxicity reference value of 2µg/kg/day was suitable as it was at the lower more conservative range provided by JECFA (WHO, 2011) and was in the no observable adverse effect range identified by RIVM (2001) and ATSDR (2007).

The WHO (2011) drinking water guideline is 0.01 mg/L based on practical considerations of treatment and analytical detection.

Oral bioavailability soil	1	Maximum
Oral bioavailability plants	1	Maximum
Oral bioavailability aquatic foods	1	Maximum
Dermal Absorption Factor	0.005	NEPM (2013)
Skin Permeability Constant	0.001	RAIS (2017)

Lead

Lead is most commonly found in one of two oxidation states: Pb(II) and Pb(IV). Lead is the most abundant heavy metal in the earth's crust. In its elemental form, lead is a dense blue-grey metal. Lead is released naturally into the environment through volcanic activity and weathering although anthropogenic sources represent a much larger source. Anthropogenic source of lead include mining, smelting, use of leaded petrol; production of lead-acid batteries, paints and use in plumbing and solder (WHO 2010)

Toxicological Effects

Adverse health effects to inorganic lead are known to include the central and peripheral nervous systems, haematopoietic system, cardiovascular system, immune system, reproductive system, gastrointestinal tract and kidneys.

Children are especially susceptible to adverse effects from lead (IARC, 2006). Irreversible brain damage or death can result in cases where blood concentrations are equal to or greater than 100μg/dL in children. Neuropsychological impairment and cognitive deficiencies (i.e. reduced IQ) have been reported at blood concentrations less than 10μg/dL (IARC 2006) suggesting there is no clear threshold for neurotoxic effects of lead in children. The blood lead level of concern has progressively decreased from 25 μg/dL to 5 μg/dL as more studies arise.

Cancer Classification

IARC has classified lead as Group 2B (Possibly carcinogenic to humans), inorganic lead compounds as Group 2B (Probably carcinogenic to humans) and organic lead compounds as Ground 3 (Not classifiable as to its carcinogenicity to humans). The USEPA has classified lead and inorganic lead compounds as Class B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals).

Adopted Toxicity Criteria and Screening Levels

Blood lead levels are considered to be the best measure of lead exposure and risk in human populations. Although a number of threshold intake criteria have been set by international agencies, several have been rescinded and it is being recognised that some health effects may occur at 'blood levels so low as to be essentially without threshold' (USEPA, 2016).

The US Centres for Disease Control and Prevention (CDC, 2012) and the Australian National Health and Medical Research Council (NHMRC, 2015) have recognised that a blood lead level of 5 μg/dl is above average and is considered to be a reference level to trigger further investigation.

JECFA PTWI, which has since been withdrawn as it was no longer considered protective of health. On the basis no new PTWI has been established and the uncertainties of adopting a blood lead model in this instance, the previous permissible tolerable weekly intake (PTWI) has been adopted.

The WHO (2011) drinking water guideline is 0.01 mg/L based on practical considerations rather than on health impacts.

Oral bioavailability soil	0.5	NEPM (2013)
Oral bioavailability plants	0.5	NEPM (2013)
Oral bioavailability aquatic foods	0.5	NEPM (2013)
Dermal Absorption Factor	0.001	NEPM (2013)
Kp	0.0001	RAIS (2017)

Mercury

Mercury exists in three oxidation states: Hg° (metallic), Hg^{+} (mercurous) and Hg^{++} (mercuric) mercury. In its elemental form, mercury is a dense, silvery-white, shiny metal, which is liquid at room temperature and boils at 357 °C. At 20 °C, the vapour pressure of the metal is 0.17 Pa (0.0013 mm Hg), and a saturated atmosphere at this temperature contains 14 mg/m^3 (WHO, 2000). Mercury vapours are odourless and colorless. Mercury compounds differ greatly in solubility and toxicity.

Mercury is produced by the mining and smelting of cinnabar ore. It is used in chloralkali plants (producing chlorine and sodium hydroxide), in paints as preservatives or pigments, in electrical switching equipment and batteries, in measuring and control equipment (thermometers, medical equipment), in mercury vacuum apparatus, as a catalyst in chemical processes, in mercury quartz and luminescent lamps, in the production and use of high explosives using mercury fulminate, in copper and silver amalgams in tooth-filling materials, and as fungicides in agriculture (WHO, 2000). Methyl mercury, one of the most toxic mercury compounds, is produced primarily by microorganisms (bacteria and fungi) in the environment, rather than by human activity.

Human Health Effects

Absorption, distribution, metabolism, and excretion of mercury is dependent upon its form and oxidation state. Organic mercurials are more readily absorbed than are inorganic forms. An oxidation-reduction cycle is involved in the metabolism of mercury and mercury compounds by both animals and humans (ATSDR 1999).

Inorganic and elemental Mercury

Most of the studies on inhalation exposure concern exposure to metallic mercury vapour (ATSDR 1999). Approximately 80% of inhaled mercury vapour is absorbed via the lungs and retained in the body. The amount retained is the same whether inhalation takes place through the nose or the mouth (WHO, 2000). Other forms of inorganic mercury do not pose a risk by the inhalation pathway. Inhalation of sufficient levels of metallic mercury vapour has been associated with systemic toxicity in both humans and animals. The major target organs of metallic mercury-induced toxicity are the kidneys and the central nervous system. At high exposure levels, respiratory, cardiovascular, and gastrointestinal effects also occur. (ATSDR, 1999). Inhalation of mercury vapour may cause irritation of the respiratory tract, renal disorders, central nervous system effects characterized by neurobehavioral changes, peripheral nervous system toxicity, renal toxicity (immunologic glomerular disease), and death (ATSDR, 1999)

Dental amalgam surfaces release mercury vapour into the mouth, and that this is the predominant source of human exposure to inorganic mercury in the general population (WHO, 2000)

Elemental mercury is poorly absorbed in the gastrointestinal tract (less than 0.01% in rats), although increased blood levels of mercury have been measured in humans following accidental ingestion of several grams of metallic mercury. Skin absorption is insignificant in relation to human exposure to mercury vapour (WHO, 2000). Dermal absorption of inorganic mercury is estimated to be in the order of 3% (RIVM, 2001). Ingestion of inorganic salts may cause severe gastrointestinal irritation, renal failure, and death with acute lethal doses in humans ranging from 1 to 4 g (ATSDR 1999). Mercury is also known to induce hypersensitivity reactions such as contact dermatitis and acrodynia (pink disease) (Mathesson et al., 1980 as cited in RAIS, 2008) (WHO, 2000).

Organic Mercury

Organic mercury, especially methyl mercury, rapidly enters the central nervous system resulting in behavioural and neuromotor disorders (ATSDR 1999). Epidemiologic studies in Japan and Iraq found ingestion of methyl mercury-contaminated food resulted in severe toxicity and death in adults and severe central nervous system effects in infants (WHO, 2000).

Mercury is actively bio-accumulated in fish and other seafood, with concentrations dependent on the particular species, habitat, maturity, weight, length, diet and the levels in the local environment. The levels of mercury measured in other food products is generally below the limit of detection. In fish and other seafood, mercury is known to bioaccumulate as the more toxic methylated species, with generally 70-85% of the total tissue mercury present as methylmercury.

Cancer Classification

IARC has classified mercury as Group 3 (unclassifiable as to carcinogenicity in humans). The USEPA has classified mercury as Class D (not classifiable as to human carcinogenicity).

IARC has classified methyl mercury as Group 2B (probable carcinogenic to humans, sufficient evidence in animals). The USEPA has classified arsenic as Class C (possibly carcinogenic to humans).

Mercury and methyl mercury have been assessed based on threshold effects.

Adopted Toxicity Criteria and Screening Levels

Inorganic Mercury

Studies on humans indicate the LOAELs for mercury vapour are around 15–30 μg/m^3. The WHO applied an uncertainty factor of 20 (10 for uncertainty due to variable sensitivities in higher risk populations and, on the basis of dose–response information, a factor of 2 to extrapolate from a LOAEL to a likely no-observed- adverse-effect level (NOAEL)), to establish a guideline for inorganic mercury vapour of 1 μg/m^3 as an annual average (WHO, 2000).

Based on a NOAEL of 0.23 mg/kg per day in a oral gavage study in rats (including an extrapolation factor of 10 to humans and 10 for human variability), an intermediate minimal risk level of 2 μg/kg per day was derived for inorganic mercury (ATSDR, 1999).

An oral Chronic Reference Dose for inorganic mercury of 0.0003 (mg/kg per day) was establish by the US EPA for mercuric chloride, based on immunologic glomerulonephritis (IRIS, 1995).

A review of mercury by JECFA (WHO, 2011a) indicated that the predominant form of mercury indoors, other than fish and shellfish, is inorganic mercury and, while data on speciation is limited, the toxicological database on mercury (II) chloride was relevant for establishing a PTWI for foodborne inorganic mercury. A PTWI was established on the bases of a benchmark dose approach, where the BMDL10 of 0.06 mg/kg/day for relative kidney weight increases in male rates was considered as the point of departure and a 100 fold uncertainty factor was applied. A PTWI for inorganic mercury of 4 μg/kg bw has been established (WHO, 2011).

Oral bioavailability soil	1	Maximum
Oral bioavailability plants	1	Maximum
Oral bioavailability aquatic foods	1	Maximum
Dermal Absorption Factor	0.0001	NEPM (2013)
Skin Permeability Constant	0.001	RAIS (2017)

Organic Mercury

The US EPA derived a subchronic and chronic oral RfD of 0.0001 mg/kg/day for methyl mercury based on a benchmark dose of 1.1 μg/kg/day for neurologic developmental abnormalities in human infants (IRIS 2008). An inhalation RfC for methyl mercury has not been determined.

An evaluation by JECFA (WHO 2004) derived a PTWI of 0.0016 mg/kg based on a steady state intake of 1.5 μg/kg/day. The PTWI was based on a review of mercury in hair and blood, a benchmark dose approach to assess the relationship between maternal hair concentrations and foetal neurotoxicity and a pharmacokinetic model. This intake is estimated to represent the exposure that would be expected to have no appreciable adverse effects on children and applying an uncertainty factor of 6.4.

Oral bioavailability soil	1	Maximum
Oral bioavailability plants	1	Maximum
Oral bioavailability aquatic foods	1	Maximum
Dermal Absorption Factor	0.001	NEPM (2013)
Skin Permeability Constant	0.001	RAIS (2017)

Zinc

Zinc is one of the most abundant heavy metals in the earth's crust. Zinc is found in the air, soil, and water, and is widely distributed in food. A common use for zinc is to coat steel and iron as well as other metals to prevent rust and corrosion. Metallic zinc is also mixed with other metals to form alloys such as brass and bronze. Zinc enters the air, water, and soil as a result of both natural and anthropogenic activities. Most zinc enters the environment as a result of mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes (ASTDR, 2005).

Human Health Effects

Zinc is an essential nutrient in humans and animals that is necessary for the function of a large number of metalloenzymes. Zinc deficiency has been associated with adverse effects in human and animals, such as dermatitis, anorexia, growth retardation, poor wound healing, hypogonadism with impaired reproductive capacity, depressed mental function, and an increased incidence of congenital malformations in infants with zinc deficiency in the mothers (ASTDR, 2005).

Excessive exposure to zinc has also been associated with toxic effects. Acute toxicity has been observed following the ingestion of excessive amounts of zinc salts, either accidentally or deliberately as an emetic or dietary supplement. Vomiting usually occurs after the consumption of more than 500 mg of zinc sulfate. Fever, nausea, vomiting, stomach cramps, and diarrhoea have been reported in people following the consumption of beverages kept in galvanized containers (WHO, 2003).

The critical effect following excessive zinc ingestion is copper deficiency. Copper deficiency has been caused by zinc therapy (150–405 mg/day) for a range of conditions and impairment of the copper status of volunteers has been reported in volunteers consuming of 18.5 mg of zinc per day in the diet (WHO, 2003).

Acute toxic effects including pulmonary distress, fever, chills, and gastroenteritis have been reported in industrial workers exposed to zinc fumes (WHO, 2003).

Available studies have not presented reproductive or developmental effects (ATSDR, 2005). Dermal exposure may result in skin irritation.

Available studies in humans and animals are inadequate to assess the carcinogenicity of zinc compounds. The US EPA currently classifies zinc and compounds as carcinogenicity group D (not classifiable as to human carcinogenicity) (ATSDR, 2005).

Cancer Classification

IARC has not assessed zinc within the monographs on the evaluation of carcinogenic risks to humans. The USEPA has classified zinc as Class D (not classifiable as to human carcinogenicity).

Zinc has been assessed based on threshold effects.

Adopted Toxicity Criteria and Screening Levels

The Joint FAO/WHO Expert Committee on Food Additives (1982) proposed a daily dietary requirement of zinc of 0.3 mg/kg bw and a provisional maximum tolerable daily intake (PMTDI) of 1.0 mg/kg bw. The report notes that there is a wide margin between nutritionally required amounts of zinc and levels that are likely to cause toxicity.

The National Environment Protection Measures (NEPC, 2013) recommended that a value of 0.5 mg/kg bw/day based on a UL of 7 mg/day for a 15 kg child (NHMRC, 2006). It is noted that FSANZ (2011) reviewed the basis for the derivation for the UL in infants (NHMRC, 2006) and noted deficiencies in the pivotal study which indicate an overly conservative basis for the UL.

Oral bioavailability soil	1	Maximum
Oral bioavailability plants	1	Maximum
Oral bioavailability aquatic foods	1	Maximum
Dermal Absorption Factor	0.001	NEPM (2013)
Skin Permeability Constant	0.0006	RAIS (2017)

Guideline levels identified but not adopted

NHMRC (2006) has established an Upper Level of Intake (UL) for various population groups including infants, children and adolescents, adults, and pregnant and lactating females (refer to the Table below).

Table 1: Upper level of intake for zinc in population sub-groups.

Age	UL
Infants	
0-6 months	4 mg/day
7-12 months	5 mg/day
Children and adolescents	
1-3 years	7 mg/day
4-8 years	12 mg/day
9-13 years	25 mg/day
14-18 years	35 mg/day
Adults (19 years and over)	
Men	40 mg/day
Women	40 mg/day
Pregnancy and lactation	
14-18 years	35 mg/day
19-50 years	40 mg/day

The critical effect in adults was an adverse effect of zinc on copper metabolism. A UL of 40 mg/day was established based on a LOAEL of 60 mg/day and the application of an uncertainty factor of 1.5 to account for inter-individual variability sensitivity, and for extrapolation from the LOAEL to NOAEL. No data were identified to justify a different UL in pregnant or lactating women, therefore the same levels were established to that of the equivalent non-pregnant woman.

For infants, a UL of 4 mg/day was established on the basis of a study in 68 infants administered 4.5 mg/day zinc in infant formula. No adverse effects were identified. As no data were available for older children or adolescents these data were adjusted on a body weight basis.

IRIS (2005) recommended a daily intake of 0.3mg/(kg day) based on human studies.

Sulfur dioxide (SO_2)

Health effects

A comprehensive and current review of the health effects of SO_2 was published by the U.S. EPA (2017) as the Integrated Science Assessment for SO_2. This review identified that exacerbation of asthma in children and possibly impaired lung function in adults are the main health effects of concern. These health effects can follow short term (up to one month) and long term (1 month to years) exposure.

Acute Exposures

Short term SO_2 exposure is causally related to respiratory morbidity, particularly exacerbation in individuals with asthma (decreased lung function seen in the range 77-230 $\mu g/m^3$) and increased respiratory symptoms (range 154-385 $\mu g/m^3$). There is some limited and inconsistent evidence for other SO_2-related respiratory effects including exacerbation of chronic obstructive pulmonary disease (COPD) in individuals with COPD and other respiratory effects including respiratory infection, aggregated respiratory conditions, and respiratory mortality in the general population.

Chronic Exposures

Long term exposure to SO_2 may cause a variety of respiratory effects, mainly the development of asthma in children. The evidence is suggestive but not confirmed as causal.

Many studies of SO_2-related contributions to cardiovascular effects, reproductive and developmental effects, total mortality and cancer do not provide adequate evidence for a causal relationship, whether from short or long-term exposure.

Setting air quality standards

Different jurisdictions have developed various procedures to establish standards and objectives for ambient SO_2 concentrations, but all have the same common elements:

- Review of pollution effects literature
- Review of what other jurisdictions have set as an objective or standard
- Assessment of the economic implications of a particular objective or standard.

Typically, a scientific panel is established which looks at all the data and makes a recommendation to government on the level of objective or standard and its implications to public health, the environment and the economy.

In general, jurisdictions develop either standards, which represent maximum allowable (i.e., not to exceed) ground level SO_2 concentrations that can be applied in an industrial area, or standards or objectives which represent general ambient concentrations that a jurisdiction would like to attain. Although health protection is the common factor, the standards as set by various countries or international bodies, may show a wide range in threshold level, averaging period and the number of allowable exceedances. Averaging periods are typically 1-hour, 24-hour and annual. Some jurisdictions also consider shorter term periods (4, 10, 15 or 20-minutes) or mid-range periods (3-hour, 8-hour or 30-days), while some apply criteria over several months during the winter period.

Current national standards

The most relied on existing ambient air quality (AAQ) standards are those of the WHO and USEPA. Many national AAQ standards are derived from, or defer to, these standards.

Criteria for 1-hour average concentrations have been adopted by many countries and cover a wide range of values. The most stringent level is 150 $\mu g/m^3$ adopted by China for specially protected areas, while the least stringent levels are 900 $\mu g/m^3$ for Indonesia.

Many countries have adopted a 24-hour average SO_2 criterion, but there is no consistency in the levels chosen by various jurisdictions and values range from 20 μg/m^3 to 365 μg/m^3. Annual values are sometimes set for secondary considerations such as environmental protection. The table below shows some selected national AAQ targets. Numbers in parenthesis are the number of allowable exceedances; when the threshold is expressed as a percentile value, the percentile is indicated by the suffix P.

Table 1:International SO2 AAQ standards [μg/m^3]

Pollutant Average period	**SO_2 hourly**	**SO_2 daily**	**SO_2 annual**
Australia a	530 (1)	210 (1)	53 (0)
Canada a	182*[1]	-	13
China a	500 (0)	150 (0)	60 (0)
India	-	80 (98P)	50 (0)
New Zealand	350 (9); 570 (0)	-	-
USA	200 (99P*)	-	-
EU	350 (24)	125 (3)	-
UK	350 (24)	125	20
Sweden	350	125	5
WHO	-	20 (0)	-

a applicable at (urban) background locations only

** 99 percentile of 1-hour daily maximum;*

[1] Applies from 2020

() The number of allowable exceedances

P The threshold is expressed as a percentile value.

The most recent published national assessment of SO_2 is the USEPA Integrated Science Assessment (2017). The USEPA standard is a 1-hour level of 195 μg/m^3 (75 ppb) in the form of a 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour concentrations. The USEPA argues that a 1-hour standard will provide protection against SO_2-related health effects associated with short-term exposures ranging from 5 minutes to 24 hours. This standard will limit exposures associated with the adverse respiratory effects in asthmatics following 5−10 minutes exposures as well as the more serious health associations (e.g., respiratory-related emergency department visits and hospitalisations) reported in epidemiologic studies that mostly used daily metrics (1-hour daily maximum and 24-hour average). i.e., the 1-hour standard at 75 ppb would generally maintain 24-hour and annual SO2 concentrations well below the AAQ standard in the context of the lack of evidence indicating the need for such longer-term standards. Other national jurisdictions with a 1-hour SO_2 AAQ standard includes the European Union, United Kingdom, Sweden and New Zealand, all of which have 1-hour AAQ standards of 350 μg/m^3.

The WHO has not set a 1-hour standard for SO_2. It revised its AQG for SO_2 of 125 μg/m3 (24-hour mean, set in 2000) to the current target of 20 μg/m^3 (24-hour) set in 2005. It maintains Interim target-1 at 125 μg/m^3 and Interim target-2 at 50 μg/m^3, and a 10 minute average of 500 μg/m^3.

Policy considerations

Similar to the WHO standards, the USEPA standards are aspirational in the sense that they will be exceeded in many locations around the country. Setting the standards will however, help to drive policy measures to limit and reduce pollutant levels. In a highly industrialised country such as the US SO_2 is just one of many air pollutants which add to the burden of disease and stricter standards are appropriate.

In setting an AAQ goal for the Project, consideration should be given to the relatively pristine natural environment with few pre-existing air quality issues, meaning that emissions from diesel consumed by the power generators and mining equipment will not be mixed with the diverse and large range of pollutants seen in industrialised urban centres in other countries. This means that air-pollution-related adverse health effects if any, can be more directly linked to the emissions from the Project activities without confounding from other sources and means that air quality monitoring for SO_2 is a viable and even necessary risk management strategy.

It is noteworthy that the Global Burden of Disease studies indicate that Papua New Guinea (PNG) has a higher rate of mortality (31.5 deaths/100,000) due to asthma than most countries in Oceania. However, the deaths occur primarily in adults >40 years and the major contributors are tobacco smoke and occupational exposure. The WHO reports that the incidence of asthma in children in PNG is 'virtually zero' [1].

Recommendations

Based on the evaluation above a 1-hour standard of 350 µg/m^3 AAQ standard for SO_2 has been selected as follows:

- Adopt a 1-hour standard for SO_2 rather than a 24-hour standard in accordance with the USEPA arguments.
- Adopt a 350 µg/m^3 AAQ standard for SO_2. This should be reported as a 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour concentrations. This value is used in many developed jurisdictions as noted above and will provide protection for all but the most sensitive population members, which given the insignificant rate of asthma in children in PNG will be very few.

As a risk management strategy, establish AAQ monitoring stations at appropriate locations around the Project. This could also include campaigns of personal monitoring of SO_2 to verify the monitoring station results.

[1] http://www.who.int/mediacentre/factsheets/fs206/en/

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Appendix E - Baseline Exposure Calculations

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Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Drinking water: Study Area 1 (Tier 1)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 1 P1Bd (ig) t

BASELINE Ingestion drinking water - primary source. LWR catchments and tributary waterways, or groundwater. Study Area 1 (Tier 1)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/d	1	2
Exposure Frequency	days/year	60	60
Averaging Time	years	5	65

$$CDI_{drinking} = \frac{C_W \times IR_{DW} \times B_a \times EF \times ED \times F_{ucs}}{365 \, {}^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc (mg/L)	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake (mg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	Estimated chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	6.8E-04	100%	100%	2.00E-03	1.00	9.34E-06	4.7E-03
Lead	7.3E-04	100%	100%	3.50E-03	1.00	9.96E-06	2.8E-03
Mercury	5.0E-05	100%	100%	6.00E-04	1.00	6.85E-07	1.1E-03
Zinc	5.1E-03	100%	100%	5.00E-01	1.00	6.97E-05	1.4E-04
						Total HI	**<0.01**
Adult							**Adult**
Arsenic	6.8E-04	100%	100%	2.00E-03	1.00	4.08E-06	2.0E-03
Lead	7.3E-04	100%	100%	3.50E-03	1.00	4.35E-06	1.2E-03
Mercury	5.0E-05	100%	100%	6.00E-04	1.00	2.99E-07	5.0E-04
Zinc	5.1E-03	100%	100%	5.00E-01	1.00	3.04E-05	6.1E-05
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 2 W1Ap (ig) t

BASELINE Ingestion drinking water -secondary source. LWR catchments and tributary waterways, or groundwater. Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/d	1	2
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

$$CDI_{Drinking} = \frac{C_W \times IR_{DW} \times B_e \times EF \times ED \times F_{test}}{365 \, {}^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc (mg/L)	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake (mg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	Estimated chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	1.33E-05	6.6E-03
Lead	1.0E-03	100%	100%	3.50E-03	1.00	8.33E-05	2.4E-02
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	8.33E-06	1.4E-02
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	8.33E-04	1.7E-03
						Total HI	**0.05**
Adult							**Adult**
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	5.79E-06	2.9E-03
Lead	1.0E-03	100%	100%	3.50E-03	1.00	3.64E-05	1.0E-02
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	3.64E-06	6.1E-03
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	3.64E-04	7.3E-04
						Total HI	**0.02**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 3 S1Cd (ig) t

BASELINE Ingestion drinking water - primary source. Lower Watut River. Study Area 1 (Tier 2)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/d	1	2
Exposure Frequency	days/year	60	60
Averaging Time	years	5	65

$$CDI_{drinking} = \frac{C_W \times IR_{DW} \times B_a \times EF \times ED \times F_{UCS}}{365 \,{}^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc (mg/L)	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake (mg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	Estimated chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	2.18E-06	1.1E-03
Lead	1.0E-03	100%	100%	3.50E-03	1.00	1.37E-05	3.9E-03
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	1.37E-06	2.3E-03
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	1.37E-04	2.7E-04
						Total HI	**<0.01**
Adult							**Adult**
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	9.52E-07	4.8E-04
Lead	1.0E-03	100%	100%	3.50E-03	1.00	5.98E-06	1.7E-03
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	5.98E-07	1.0E-03
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	5.98E-05	1.2E-04
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: Lower Watut River
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 4 S1Ap (ig) t

BASELINE Ingestion drinking water -Secondary source. Lower Watut River. Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/d	1	2
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

$$CDI_{Drinking} = \frac{C_W \times IR_{DW} \times B_e \times EF \times ED \times F_{src}}{365\,{}^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc (mg/L)	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake (mg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	Estimated chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	1.0E-04	100%	100%	2.00E-03	1.00	8.33E-06	4.2E-03
Lead	1.0E-02	100%	100%	3.50E-03	1.00	8.33E-04	2.4E-01
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	8.33E-06	1.4E-02
Zinc	1.8E-02	100%	100%	5.00E-01	1.00	1.50E-03	3.0E-03
						Total HI	**0.26**
Adult							**Adult**
Arsenic	1.0E-04	100%	100%	2.00E-03	1.00	3.64E-06	1.8E-03
Lead	1.0E-02	100%	100%	3.50E-03	1.00	3.64E-04	1.0E-01
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	3.64E-06	6.1E-03
Zinc	1.8E-02	100%	100%	5.00E-01	1.00	6.55E-04	1.3E-03
						Total HI	**0.11**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 7 W1Ao (ig) t

BASELINE Incidental ingestion water during other activities (ie bathing, cleaning, washing, irrigation etc). LWR catchments and tributary waterways. Study Area 1

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/hour	0.025	0.0125
Exposure Frequency	days/year	365	365
Exposure Time	hour/day	0.13	0.9
Averaging Time	years	5	65

$$CDI_{wing} = \frac{C_W \times IR_W \times B_c \times ET \times EF \times ED \times F_{ucs}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc	Fraction of water from source	Bioavailability	Tolerable Intake	% TDI Allocated to Contaminated Sites	Estimated Chronic Daily Intake	Estimated
	mg/L	(unitless)	(unitless)	mg/kg-day	(unitless)	(mg/kg-day)	HQ
Child							
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	4.31E-08	2.2E-05
Lead	1.0E-03	100%	100%	3.50E-03	1.00	2.71E-07	7.7E-05
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	2.71E-08	4.5E-05
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	2.71E-06	5.4E-06
						Total HI	**<0.01**
Adult							
Arsenic	1.6E-04	100%	100%	2.00E-03	1.00	3.26E-08	1.6E-05
Lead	1.0E-03	100%	100%	3.50E-03	1.00	2.05E-07	5.8E-05
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	2.05E-08	3.4E-05
Zinc	1.0E-02	100%	100%	5.00E-01	1.00	2.05E-06	4.1E-06
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 32 W1Ao (dc) t

BASELINE Dermal contact with water whilst washing in LWC catchment waterways. Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Exposure Frequency	days/year	365	365
Exposure Time	hours/day	0.13	0.9
Averaging Time	years	5	65
Exposed Skin Area	cm^2	7545	18200

$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365 \, {}^{days}/_{year} \times AT \times BW}$$

Source: Baseline Surface Water: LWR catchment waterways.

Chemical	COPC Concentration Baseline Surface Water: LWR catchment waterways.	Tolerable Intake - Dermal	Skin Permeability	Fraction TDI Allocated to Contaminated Site	Estimated Intake	Estimated HQ
	µg/kg	µg/kg-day	(cm^2/hour)	unitless	(µg/kg-day)	Dermal
Child						
Arsenic	0.16	2	1.6E-04	1	1.30E-05	6.51.E-06
Copper	2.00	140	2.0E-03	1	1.63E-04	1.17.E-06
Mercury	0.10	0.6	1.0E-04	1	8.17E-06	1.36.E-05
Selenium	10.00	6	1.0E-02	1	8.17E-04	1.36.E-04
Zinc	10.00	500	6.0E-03	1	4.90E-04	9.81.E-07
					Total HI	**<0.01**
Adult						
Arsenic	0.16	2	1.6E-04	1	4.74E-05	2.37.E-05
Copper	2.00	140	2.0E-03	1	5.96E-04	4.25.E-06
Mercury	0.10	0.6	1.0E-04	1	2.98E-05	4.96.E-05
Selenium	10.00	6	1.0E-02	1	2.98E-03	4.96.E-04
Zinc	10.00	500	6.0E-03	1	1.79E-03	3.57.E-06
					Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: Lower Watut River
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 8 S1Ao (ig) t

BASELINE Incidental ingestion water during other activities (ie bathing, cleaning, washing, irrigation etc). - LWR. Study Area 1

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/hour	0.025	0.0125
Exposure Frequency	days/year	365	365
Exposure Time	hour/day	0.13	0.9
Averaging Time	years	5	65

$$CDI_{wing} = \frac{C_W \times IR_W \times B_c \times ET \times EF \times ED \times F_{ucs}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc mg/L	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake mg/kg-day	% TDI Allocated to Contaminated Sites (unitless)	Estimated Chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							
Arsenic	1.0E-04	100%	100%	2.00E-03	1.00	2.71E-08	1.4E-05
Lead	1.0E-02	100%	100%	3.50E-03	1.00	2.71E-06	7.7E-04
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	2.71E-08	4.5E-05
Zinc	1.8E-02	100%	100%	5.00E-01	1.00	4.88E-06	9.8E-06
						Total HI	**<0.01**
Adult							
Arsenic	1.0E-04	100%	100%	2.00E-03	1.00	2.05E-08	1.0E-05
Lead	1.0E-02	100%	100%	3.50E-03	1.00	2.05E-06	5.8E-04
Mercury	1.0E-04	100%	100%	6.00E-04	1.00	2.05E-08	3.4E-05
Zinc	1.8E-02	100%	100%	5.00E-01	1.00	3.68E-06	7.4E-06
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: Lower Watut River
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 33 S1Ao (dc) t

BASELINE Dermal contact with water whilst washing in LWC. Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Exposure Frequency	days/year	365	365
Exposure Time	hours/day	0.13	0.9
Averaging Time	years	5	65
Exposed Skin Area	cm^2	7545	18200

$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365\ {}^{days}/_{year} \times AT \times BW}$$

Forward

Source: Baseline Surface Water: Lower Watut River

Chemical	COPC Concentration Baseline Surface Water: Lower Watut River	Tolerable Intake - Dermal	Skin Permeability	Fraction TDI Allocated to Contaminated Site	Estimated Intake	Estimated HQ
	µg/kg	µg/kg·day	(cm^2/hour)	unitless	(µg/kg-day)	Dermal
Child						
Arsenic	0.10	2	1.0E-04	1	8.17E-06	4.09.E-06
Copper	10.00	140	1.0E-02	1	8.17E-04	5.84.E-06
Mercury	0.10	0.6	1.0E-04	1	8.17E-06	1.36.E-05
Selenium	10.00	6	1.0E-02	1	8.17E-04	1.36.E-04
Zinc	18.00	500	1.1E-02	1	8.83E-04	1.77.E-06
					Total HI	**<0.01**
Adult						
Arsenic	0.10	2	1.0E-04	1	2.98E-05	1.49.E-05
Copper	10.00	140	1.0E-02	1	2.98E-03	2.13.E-05
Mercury	0.10	0.6	1.0E-04	1	2.98E-05	4.96.E-05
Selenium	10.00	6	1.0E-02	1	2.98E-03	4.96.E-04
Zinc	18.00	500	1.1E-02	1	3.22E-03	6.43.E-06
					Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 9 W1Ak (ig) t

BASELINE Incidental ingestion water during recreational activities (swimming). LWR catchments and tributary waterways. Study Area 1.

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/hour	0.05	0.025
Exposure Frequency	days/year	365	365
Exposure Time	hour/day	0.5	1
Averaging Time	years	5	65

$$CDI_{wing} = \frac{C_w \times IR_w \times B_c \times ET \times EF \times ED \times F_{wcs}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc mg/L	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake mg/kg-day	% TDI Allocated to Contaminated Sites (unitless)	Estimated Chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	1.6E-04	100%	100%	0.002	1.00	3.32E-07	1.7E-04
Lead	1.0E-03	100%	100%	0.004	1.00	2.08E-06	6.0E-04
Mercury	1.0E-04	100%	100%	0.0006	1.00	2.08E-07	3.5E-04
Zinc	1.0E-02	100%	100%	0.500	1.00	2.08E-05	4.2E-05
						Total HI	**<0.01**
Adult							**Adult**
Arsenic	1.6E-04	100%	100%	0.002	1.00	7.24E-08	3.6E-05
Lead	1.0E-03	100%	100%	0.004	1.00	4.55E-07	1.3E-04
Mercury	1.0E-04	100%	100%	0.0006	1.00	4.55E-08	7.6E-05
Zinc	1.0E-02	100%	100%	0.500	1.00	4.55E-06	9.1E-06
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: LWR catchment waterways.
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 27 W1Ak (dc) t

BASELINE Dermal contact with water whilst swimming in LWC catchment waterways. Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Exposure Frequency	days/year	365	365
Exposure Time	hours/day	0.5	1
Averaging Time	years	5	65
Exposed Skin Area	cm^2	7545	18200

$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365\ ^{days}/_{year} \times AT \times BW}$$

Forward

Source: Baseline Surface Water: LWR catchment waterways.

Chemical	COPC Concentration Baseline Surface Water: LWR catchment waterways. µg/kg	Tolerable Intake - Dermal µg/kg-day	Skin Permeability (cm^2/hour)	Fraction TDI Allocated to Contaminated Site unitless	Estimated Intake (µg/kg-day)	Estimated HQ Dermal
Child						
Arsenic	0.16	2	1.6E-04	1	5.00E-05	2.50.E-05
Copper	2.00	140	2.0E-03	1	6.29E-04	4.49.E-06
Mercury	0.10	0.6	1.0E-04	1	3.14E-05	5.24.E-05
Selenium	10.00	6	1.0E-02	1	3.14E-03	5.24.E-04
Zinc	10.00	500	6.0E-03	1	1.89E-03	3.77.E-06
					Total HI	**<0.01**
Adult						
Arsenic	0.16	2	1.6E-04	1	5.27E-05	2.63.E-05
Copper	2.00	140	2.0E-03	1	6.62E-04	4.73.E-06
Mercury	0.10	0.6	1.0E-04	1	3.31E-05	5.52.E-05
Selenium	10.00	6	1.0E-02	1	3.31E-03	5.52.E-04
Zinc	10.00	500	6.0E-03	1	1.99E-03	3.97.E-06
					Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: Lower Watut River
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 10 S1Ak (ig) t

BASELINE Incidental ingestion water during recreational activities (swimming). LWR. Study Area 1.

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/hour	0.05	0.025
Exposure Frequency	days/year	365	365
Exposure Time	hour/day	0.5	1
Averaging Time	years	5	65

$$CDI_{wing} = \frac{C_W \times IR_W \times B_z \times ET \times EF \times ED \times F_{ucz}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc	Fraction of water from source	Bioavailability	Tolerable Intake	% TDI Allocated to Contaminated Sites	Estimated Chronic Daily Intake	Estimated
	mg/L	(unitless)	(unitless)	mg/kg-day	(unitless)	(mg/kg-day)	HQ
Child							**Child**
Arsenic	1.0E-04	100%	100%	0.002	1.00	2.08E-07	1.0E-04
Lead	1.0E-02	100%	100%	0.004	1.00	2.08E-05	6.0E-03
Mercury	1.0E-04	100%	100%	0.0006	1.00	2.08E-07	3.5E-04
Zinc	1.8E-02	100%	100%	0.500	1.00	3.75E-05	7.5E-05
						Total HI	**<0.01**
Adult							**Adult**
Arsenic	1.0E-04	100%	100%	0.002	1.00	4.55E-08	2.3E-05
Lead	1.0E-02	100%	100%	0.004	1.00	4.55E-06	1.3E-03
Mercury	1.0E-04	100%	100%	0.0006	1.00	4.55E-08	7.6E-05
Zinc	1.8E-02	100%	100%	0.500	1.00	8.18E-06	1.6E-05
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Baseline Surface Water: Lower Watut River
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 28 S1Ak (dc) t

BASELINE Dermal contact with water whilst swimming in LWC. Study Area 1

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Exposure Frequency	days/year	365	365
Exposure Time	hours/day	0.5	1
Averaging Time	years	5	65
Exposed Skin Area	cm^2	7545	18200

$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365\ ^{days}/_{year} \times AT \times BW}$$

Source: Baseline Surface Water: Lower Watut River

Chemical	COPC Concentration Baseline Surface Water: Lower Watut River	Tolerable Intake - Dermal	Skin Permeability	Fraction TDI Allocated to Contaminated Site	Estimated Intake	Estimated HQ
	µg/kg	µg/kg-day	(cm^2/hour)	unitless	(µg/kg-day)	Dermal
Child						
Arsenic	0.10	2	1.0E-04	1	3.14E-05	1.57.E-05
Copper	10.00	140	1.0E-02	1	3.14E-03	2.25.E-05
Mercury	0.10	0.6	1.0E-04	1	3.14E-05	5.24.E-05
Selenium	10.00	6	1.0E-02	1	3.14E-03	5.24.E-04
Zinc	18.00	500	1.1E-02	1	3.40E-03	6.79.E-06
					Total HI	**<0.01**
Adult						
Arsenic	0.10	2	1.0E-04	1	3.31E-05	1.65.E-05
Copper	10.00	140	1.0E-02	1	3.31E-03	2.36.E-05
Mercury	0.10	0.6	1.0E-04	1	3.31E-05	5.52.E-05
Selenium	10.00	6	1.0E-02	1	3.31E-03	5.52.E-04
Zinc	18.00	500	1.1E-02	1	3.57E-03	7.15.E-06
					Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Huon Gulf: Coastal marine water
Receptor: Villager in Coastal Stoastal Study Areas 3 and 4
Scenario ID: 22 HCAk (ig) t

BASELINE Incidental ingestion water during recreational activities (swimming). Coastal areas - Study Areas 3 and 4.

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	L/hour	0.05	0.025
Exposure Frequency	days/year	365	365
Exposure Time	hour/day	0.5	1
Averaging Time	years	5	65

$$CDI_{wing} = \frac{C_W \times IR_W \times B_c \times ET \times EF \times ED \times F_{acc}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	Groundwater Conc mg/L	Fraction of water from source (unitless)	Bioavailability (unitless)	Tolerable Intake mg/kg-day	% TDI Allocated to Contaminated Sites (unitless)	Estimated Chronic Daily Intake (mg/kg-day)	Estimated HQ
Child							**Child**
Arsenic	1.6E-03	100%	100%	0.002	1.00	3.26E-06	1.6E-03
Lead	2.1E-04	100%	100%	0.004	1.00	4.29E-07	1.2E-04
Mercury	4.1E-05	100%	100%	0.0006	1.00	8.59E-08	1.4E-04
Zinc	4.8E-03	100%	100%	0.500	1.00	9.93E-06	2.0E-05
						Total HI	**<0.01**
Adult							**Adult**
Arsenic	1.6E-03	100%	100%	0.002	1.00	7.11E-07	3.6E-04
Lead	2.1E-04	100%	100%	0.004	1.00	9.36E-08	2.7E-05
Mercury	4.1E-05	100%	100%	0.0006	1.00	1.87E-08	3.1E-05
Zinc	4.8E-03	100%	100%	0.500	1.00	2.17E-06	4.3E-06
						Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Huon Gulf: Coastal marine water
Receptor: Villager in Coastal Studyal Study Areas 3 and 4
Scenario ID: 29 HCAk (dc) t

BASELINE Dermal contact with water whilst swimming in coastal waters. Study Areas 3 and 4

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Exposure Frequency	days/year	365	365
Exposure Time	hours/day	0.5	1
Averaging Time	years	5	65
Exposed Skin Area	cm^2	7545	18200

$$CDI_{Dermal} = \frac{C_W \times CF_1 \times ED \times ET \times P \times EF \times AR}{365\ ^{days}/_{year} \times AT \times BW}$$

Forward

Source: Huon Gulf: Coastal marine water

Chemical	COPC Concentration Huon Gulf: Coastal marine water	Tolerable Intake - Dermal	Skin Permeability	Fraction TDI Allocated to Contaminated Site	Estimated Intake	Estimated HQ
	µg/kg	µg/kg·day	(cm^2/hour)	unitless	(µg/kg-day)	Dermal
Child						
Arsenic	1.56	2	1.6E-03	1	4.92E-04	2.46.E-04
Copper	1.11	140	1.1E-03	1	3.50E-04	2.50.E-06
Mercury	0.04	0.6	4.1E-05	1	1.30E-05	2.16.E-05
Selenium	3.41	6	3.4E-03	1	1.07E-03	1.78.E-04
Zinc	4.76	500	2.9E-03	1	8.99E-04	1.80.E-06
					Total HI	**<0.01**
Adult						
Arsenic	1.56	2	1.6E-03	1	5.18E-04	2.59.E-04
Copper	1.11	140	1.1E-03	1	3.68E-04	2.63.E-06
Mercury	0.04	0.6	4.1E-05	1	1.36E-05	2.27.E-05
Selenium	3.41	6	3.4E-03	1	1.13E-03	1.88.E-04
Zinc	4.76	500	2.9E-03	1	9.46E-04	1.89.E-06
					Total HI	**<0.01**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 1. Freshwater fish
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 11 S1Af (ig) t

BASELINE Ingestion of freshwater fish - Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.12	0.18
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AF} \times IR_{AF} \times B_a \times EF \times ED \times F_{TFF}}{365 \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 1. Freshwater fish µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of freshwater fish - Study Area 1 HQ
Child							**Child**
Arsenic	8.4	100%	100%	2	0.09	1.00	4.32E-02
Lead	21	100%	100%	4	0.22	1.00	6.23E-02
Mercury	66	100%	100%	0.23	0.68	1.00	2.96E+00
Zinc	22544	100%	100%	500	230.81	1.00	4.62E-01
						Total HI	**3.52**
Adult							**Adult**
Arsenic	8.4	100%	100%	2	0.03	1.00	1.41E-02
Lead	21	100%	100%	4	0.07	1.00	2.04E-02
Mercury	66	100%	100%	0.23	0.22	1.00	9.69E-01
Zinc	22544	100%	100%	500	75.60	1.00	1.51E-01
0.00E+00							
						Total HI	**1.15**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 1. Freshwater crustaceans
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 12 S1Ac (ig) t

BASELINE Ingestion of freshwater crustaceans - Study Area 1

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.00	0.00
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_x \times EF \times ED \times F_{TTT}}{365 \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 1. Freshwater crustaceans µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of freshwater crustaceans - Study Area 1 HQ
Child							**Child**
Arsenic	105.2	100%	100%	2	0.04	1.00	1.82E-02
Lead	114	100%	100%	4	0.04	1.00	1.12E-02
Mercury	42	100%	100%	0.23	0.01	1.00	6.30E-02
Zinc	120880	100%	100%	500	41.73	1.00	8.35E-02
						Total HI	**0.18**
Adult							**Adult**
Arsenic	105.2	100%	100%	2	0.01	1.00	3.42E-03
Lead	114	100%	100%	4	0.01	1.00	2.12E-03
Mercury	42	100%	100%	0.23	0.00	1.00	1.19E-02
Zinc	120880	100%	100%	500	7.85	1.00	1.57E-02
0.00E+00							
						Total HI	**0.03**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 3. Marine fish
Receptor: Villager Study Area 3 Study Area 3
Scenario ID: 23 M3Af (ig) t

BASELINE Ingestion of fish. Coastal area - Study Area 3

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.03	0.08
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_x \times EF \times ED \times F_{TTT}}{365\ {}^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 3. Marine fish µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of fish. Coastal area - Study Area 3 HQ
Child							**Child**
Arsenic	225.8	100%	100%	2	0.60	1.00	3.02E-01
Lead	91	100%	100%	4	0.24	1.00	6.94E-02
Mercury	266	100%	100%	0.23	0.71	1.00	3.09E+00
Zinc	3843	100%	100%	500	10.29	1.00	2.06E-02
						Total HI	**3.48**
Adult							**Adult**
Arsenic	225.8	100%	100%	2	0.34	1.00	1.70E-01
Lead	91	100%	100%	4	0.14	1.00	3.90E-02
Mercury	266	100%	100%	0.23	0.40	1.00	1.74E+00
Zinc	3843	100%	100%	500	5.79	1.00	1.16E-02
0.00E+00							
						Total HI	**1.96**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 4. Marine fish
Receptor: Villager Study Area 4 Study Area 4
Scenario ID: 24 M4Af (ig) t

BASELINE Ingestion of fish. Coastal area - Study Area 4

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.03	0.08
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_x \times EF \times ED \times F_{TTT}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 4. Marine fish	Fraction of food from local contaminated source	Bioavailability	Tolerable Intake	Estimated Chronic Daily Intake - Terrestrial Food	% TDI Allocated to Contaminated Sites	BASELINE Ingestion of fish. Coastal area - Study Area 4
	µg/kg	(unitless)	(unitless)	µg/kg-day	(µg/kg-day)	(unitless)	HQ
Child							**Child**
Arsenic	244.9	100%	100%	2	0.66	1.00	3.28E-01
Lead	100	100%	100%	4	0.27	1.00	7.65E-02
Mercury	286	100%	100%	0.23	0.77	1.00	3.33E+00
Zinc	3086	100%	100%	500	8.27	1.00	1.65E-02
						Total HI	**3.75**
Adult							**Adult**
Arsenic	244.9	100%	100%	2	0.37	1.00	1.84E-01
Lead	100	100%	100%	4	0.15	1.00	4.30E-02
Mercury	286	100%	100%	0.23	0.43	1.00	1.87E+00
Zinc	3086	100%	100%	500	4.65	1.00	9.30E-03
0.00E+00							
						Total HI	**2.11**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 3. Crustaceans
Receptor: Villager Study Area 3 Study Area 3
Scenario ID: 25 M3Ac (ig) t

BASELINE Ingestion of crustaceans - Study Area 3

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.01	0.01
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AFing} = \frac{C_{AF} \times IR_{AF} \times B_a \times EF \times ED \times F_{TS}}{365 \, {}^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 3. Crustaceans µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of crustaceans - Study Area 3 HQ
Child							**Child**
Arsenic	150.5	100%	100%	2	0.10	1.00	5.20E-02
Lead	142	100%	100%	4	0.10	1.00	2.79E-02
Mercury	125	100%	100%	0.23	0.09	1.00	3.75E-01
Zinc	90045	100%	100%	500	62.17	1.00	1.24E-01
						Total HI	**0.58**
Adult							**Adult**
Arsenic	150.5	100%	100%	2	0.02	1.00	9.77E-03
Lead	142	100%	100%	4	0.02	1.00	5.25E-03
Mercury	125	100%	100%	0.23	0.02	1.00	7.06E-02
Zinc	90045	100%	100%	500	11.69	1.00	2.34E-02
0.00E+00							
						Total HI	**0.11**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Aquatic Food: Study Area 3. Molluscs
Receptor: Villager Study Area 3 Study Area 3
Scenario ID: 26 M3Am (ig) t

BASELINE Ingestion of molluscs - Study Area 3

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.01	0.01
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_a \times EF \times ED \times F_{TY}}{365\ {}^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Aquatic Food: Study Area 3. Molluscs µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of molluscs - Study Area 3 HQ
Child							**Child**
Arsenic	86.4	100%	100%	2	0.06	1.00	2.98E-02
Lead	326	100%	100%	4	0.23	1.00	6.43E-02
Mercury	63	100%	100%	0.23	0.04	1.00	1.88E-01
Zinc	127225	100%	100%	500	87.85	1.00	1.76E-01
						Total HI	**0.46**
Adult							**Adult**
Arsenic	86.4	100%	100%	2	0.01	1.00	5.61E-03
Lead	326	100%	100%	4	0.04	1.00	1.21E-02
Mercury	63	100%	100%	0.23	0.01	1.00	3.53E-02
Zinc	127225	100%	100%	500	16.52	1.00	3.30E-02
0.00E+00							
						Total HI	**0.09**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Fruits Study Area 1 (Tier 1)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 13 T1Br (ig) t

BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 1)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.185571429	0.291785714
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_a \times EF \times ED \times F_{TS}}{365\ \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Fruits Study Area 1 (Tier 1) µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 1) HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.04	1.00	1.93E-02
Lead	25	100%	100%	4	0.39	1.00	1.10E-01
Mercury	5	100%	100%	0.6	0.08	1.00	1.29E-01
Zinc	10188	100%	100%	500	157.54	1.00	3.15E-01
						Total HI	**0.57**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.01	1.00	6.63E-03
Lead	25	100%	100%	4	0.13	1.00	3.79E-02
Mercury	5	100%	100%	0.6	0.03	1.00	4.42E-02
Zinc	10188	100%	100%	500	54.05	1.00	1.08E-01
0.00E+00							
						Total HI	**0.20**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Fruits Study Area 1 (Tier 2)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 14 T1Cr (ig) t

BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.303714286	0.279857143
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP/ing} = \frac{C_{AP} \times IR_{AP} \times B_{s} \times EF \times ED \times F_{TSI}}{365 \, {}^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Fruits Study Area 1 (Tier 2) µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2) HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.06	1.00	3.16E-02
Lead	25	100%	100%	4	0.63	1.00	1.81E-01
Mercury	5	100%	100%	0.6	0.13	1.00	2.11E-01
Zinc	3633	100%	100%	500	91.94	1.00	1.84E-01
						Total HI	**0.61**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.01	1.00	6.36E-03
Lead	25	100%	100%	4	0.13	1.00	3.63E-02
Mercury	5	100%	100%	0.6	0.03	1.00	4.24E-02
Zinc	3633	100%	100%	500	18.48	1.00	3.70E-02
0.00E+00							
						Total HI	**0.12**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Veg/Grains Study Area 1 (Tier 1)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 14 T1Cr (ig) t

BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.303714286	0.279857143
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP/ing} = \frac{C_{AP} \times IR_{AP} \times B_s \times EF \times ED \times F_{TS}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Veg/Grains Study Area 1 (Tier 1) µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2) HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.06	1.00	3.16E-02
Lead	25	100%	100%	4	0.63	1.00	1.81E-01
Mercury	5	100%	100%	0.6	0.13	1.00	2.11E-01
Zinc	6044	100%	100%	500	152.98	1.00	3.06E-01
						Total HI	**0.73**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.01	1.00	6.36E-03
Lead	25	100%	100%	4	0.13	1.00	3.63E-02
Mercury	5	100%	100%	0.6	0.03	1.00	4.24E-02
Zinc	6044	100%	100%	500	30.76	1.00	6.15E-02
0.00E+00							
						Total HI	**0.15**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Veg/Grains Study Area 1 (Tier 2)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 14 T1Cr (ig) t

BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.303714286	0.279857143
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP ing} = \frac{C_{AP} \times IR_{AP} \times B_x \times EF \times ED \times F_{TCS}}{365 \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Veg/Grains Study Area 1 (Tier 2)	Fraction of food from local contaminated source	Bioavailability	Tolerable Intake	Estimated Chronic Daily Intake - Terrestrial Food	% TDI Allocated to Contaminated Sites	BASELINE Ingestion of local grown fruit - Study Area 1 (Tier 2)
	µg/kg	(unitless)	(unitless)	µg/kg-day	(µg/kg-day)	(unitless)	HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.06	1.00	3.16E-02
Lead	25	100%	100%	4	0.63	1.00	1.81E-01
Mercury	5	100%	100%	0.6	0.13	1.00	2.11E-01
Zinc	8	100%	100%	500	0.21	1.00	4.21E-04
						Total HI	**0.42**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.01	1.00	6.36E-03
Lead	25	100%	100%	4	0.13	1.00	3.63E-02
Mercury	5	100%	100%	0.6	0.03	1.00	4.24E-02
Zinc	8	100%	100%	500	0.04	1.00	8.45E-05
0.00E+00							
						Total HI	**0.09**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Animal Foods: Study Area 1 (Tier 1)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 17 T1Ba (ig) t

BASELINE Ingestion of local animal meat and products - Study Area 1 (Tier 1)

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.050285714	0.074357143
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP-ing} = \frac{C_{AP} \times IR_{AP} \times B_b \times EF \times ED \times F_{TDI}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Animal Foods: Study Area 1 (Tier 1)	Fraction of food from local contaminated source	Bioavailability	Tolerable Intake	Estimated Chronic Daily Intake - Terrestrial Food	% TDI Allocated to Contaminated Sites	BASELINE Ingestion of local animal meat and products - Study Area 1 (Tier 1)
	µg/kg	(unitless)	(unitless)	µg/kg-day	(µg/kg-day)	(unitless)	HQ
Child							**Child**
Arsenic	4.4	100%	100%	2	0.02	1.00	9.15E-03
Lead	25	100%	100%	4	0.10	1.00	2.99E-02
Mercury	28	100%	100%	0.6	0.12	1.00	1.96E-01
Zinc	21602	100%	100%	500	90.52	1.00	1.81E-01
						Total HI	**0.42**
Adult							**Adult**
Arsenic	4.4	100%	100%	2	0.01	1.00	2.95E-03
Lead	25	100%	100%	4	0.03	1.00	9.66E-03
Mercury	28	100%	100%	0.6	0.04	1.00	6.31E-02
Zinc	21602	100%	100%	500	29.20	1.00	5.84E-02
0.00E+00							
						Total HI	**0.13**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Animal Foods: Study Area 1 (Tier 2)
Receptor: Villager Study Area 1 Study Area 1
Scenario ID: 18 T1Ca (ig) t

BASELINE Ingestion of local animal meat and products - Study Area 1 (Tier 2)

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.106857143	0.133571429
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP,ing} = \frac{C_{AP} \times IR_{AP} \times B_p \times EF \times ED \times F_{TS}}{365 \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Animal Foods: Study Area 1 (Tier 2)	Fraction of food from local contaminated source	Bioavailability	Tolerable Intake	Estimated Chronic Daily Intake - Terrestrial Food	% TDI Allocated to Contaminated Sites	BASELINE Ingestion of local animal meat and products - Study Area 1 (Tier 2)
	µg/kg	(unitless)	(unitless)	µg/kg-day	(µg/kg-day)	(unitless)	HQ
Child							**Child**
Arsenic	4.6	100%	100%	2	0.04	1.00	2.06E-02
Lead	28	100%	100%	4	0.25	1.00	7.12E-02
Mercury	24	100%	100%	0.6	0.21	1.00	3.49E-01
Zinc	25553	100%	100%	500	227.55	1.00	4.55E-01
						Total HI	**0.90**
Adult							**Adult**
Arsenic	4.6	100%	100%	2	0.01	1.00	5.63E-03
Lead	28	100%	100%	4	0.07	1.00	1.94E-02
Mercury	24	100%	100%	0.6	0.06	1.00	9.51E-02
Zinc	25553	100%	100%	500	62.06	1.00	1.24E-01
0.00E+00							
						Total HI	**0.24**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Fruits Study Areas 3 & 4
Receptor: Villager in Coastal Study stal Study Areas 3 and 4
Scenario ID: 19 TCAr (ig) t

BASELINE Ingestion of local fruits - Coastal Study Areas 3 and 4

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.111571429	0.087714286
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{AP/ing} = \frac{C_{AP} \times IR_{AP} \times B_{o} \times EF \times ED \times F_{TOI}}{365\ \frac{days}{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Fruits Study Areas 3 & 4 µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of local fruits - Coastal Study Areas 3 and 4 HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.02	1.00	1.16E-02
Lead	25	100%	100%	4	0.23	1.00	6.64E-02
Mercury	5	100%	100%	0.6	0.05	1.00	7.75E-02
Zinc	3173	100%	100%	500	29.50	1.00	5.90E-02
						Total HI	**0.21**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.00	1.00	1.99E-03
Lead	25	100%	100%	4	0.04	1.00	1.14E-02
Mercury	5	100%	100%	0.6	0.01	1.00	1.33E-02
Zinc	3173	100%	100%	500	5.06	1.00	1.01E-02
0.00E+00							
						Total HI	**0.04**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Plant Foods: Veg/Grains Study Areas 3 & 4
Receptor: Villager in Coastal Studystal Study Areas 3 and 4
Scenario ID: 20 TCAv (ig) t

BASELINE Ingestion of local vegetables and grains - Coastal Study Areas 3 and 4

Parameters	Units	Child	Adult
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.543285714	0.517428571
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_o \times EF \times ED \times F_{TA}}{365 \, ^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Plant Foods: Veg/Grains Study Areas 3 & 4	Fraction of food from local contaminated source	Bioavailability	Tolerable Intake	Estimated Chronic Daily Intake - Terrestrial Food	% TDI Allocated to Contaminated Sites	BASELINE Ingestion of local vegetables and grains - Coastal Study Areas 3 and 4
	µg/kg	(unitless)	(unitless)	µg/kg-day	(µg/kg-day)	(unitless)	HQ
Child							**Child**
Arsenic	2.5	100%	100%	2	0.11	1.00	5.66E-02
Lead	25	100%	100%	4	1.13	1.00	3.23E-01
Mercury	5	100%	100%	0.6	0.23	1.00	3.77E-01
Zinc	5180	100%	100%	500	234.52	1.00	4.69E-01
						Total HI	**1.23**
Adult							**Adult**
Arsenic	2.5	100%	100%	2	0.02	1.00	1.18E-02
Lead	25	100%	100%	4	0.24	1.00	6.72E-02
Mercury	5	100%	100%	0.6	0.05	1.00	7.84E-02
Zinc	5180	100%	100%	500	48.73	1.00	9.75E-02
0.00E+00							
						Total HI	**0.25**

Estimation of Hazard Index

WAFI-GOLPU PROJECT
Joint Venture

Source: Terrestrial Animal Foods: Study Area 3 & 4
Receptor: Villager in Coastal Stud)stal Study Areas 3 and 4
Scenario ID: 21 TCAa (ig) t

BASELINE Ingestion of local animal meat and products - Coastal Study Areas 3 and 4

Parameters	**Units**	**Child**	**Adult**
Body Weight	kg	12	55
Exposure Duration	years	5	65
Ingestion Rate	kg/day	0.013285714	0.023857143
Exposure Frequency	days/year	365	365
Averaging Time	years	5	65

Forward

$$CDI_{APing} = \frac{C_{AP} \times IR_{AP} \times B_A \times EF \times ED \times F_{TS}}{365\ ^{days}/_{year} \times AT \times BW}$$

Chemical	COPC Concentration Food Terrestrial Animal Foods: Study Area 3 & 4 µg/kg	Fraction of food from local contaminated source (unitless)	Bioavailability (unitless)	Tolerable Intake µg/kg-day	Estimated Chronic Daily Intake - Terrestrial Food (µg/kg-day)	% TDI Allocated to Contaminated Sites (unitless)	BASELINE Ingestion of local animal meat and products - Coastal Study Areas 3 and 4 HQ
Child							**Child**
Arsenic	3.5	100%	100%	2	0.00	1.00	1.96E-03
Lead	25	100%	100%	4	0.03	1.00	7.91E-03
Mercury	32	100%	100%	0.6	0.03	1.00	5.81E-02
Zinc	32787	100%	100%	500	36.30	1.00	7.26E-02
						Total HI	**0.14**
Adult							**Adult**
Arsenic	3.5	100%	100%	2	0.00	1.00	7.66E-04
Lead	25	100%	100%	4	0.01	1.00	3.10E-03
Mercury	32	100%	100%	0.6	0.01	1.00	2.28E-02
Zinc	32787	100%	100%	500	14.22	1.00	2.84E-02
0.00E+00							
						Total HI	**0.06**

Health Risk Characterisation
Hazard Quotient - Exposure Pathway and COPC

Young Child

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water secondary source	Incidental ingestion of water bathing / cleaning / washing & irrigation purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing & gardening activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crustaceans	Ingestion of local molluscs	Total HI
Study Area 1 (Tier 1)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.07	<0.01	0.04	0.02		0.15
	Lead	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.11	0.38	0.03	0.06	0.01		0.62
	Mercury	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.44	0.20	2.96	0.06		3.80
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.32	0.64	0.18	0.46	0.08		1.68
Study Area 1 (Tier 2)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.07	0.02	0.04	0.02		0.18
	Lead	<0.01	0.24	<0.01	<0.01	<0.01	<0.01	0.18	0.39	0.07	0.06	0.01		0.96
	Mercury	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.21	0.46	0.35	2.96	0.06		4.05
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.18	<0.01	0.46	0.46	0.08		1.18
Study Area 3	Arsenic				<0.01		<0.01	0.01	0.06	<0.01	0.30	0.05	0.03	0.45
	Lead				<0.01		<0.01	0.07	0.32	<0.01	0.07	0.03	0.06	0.55
	Mercury				<0.01		<0.01	0.08	0.38	0.06	3.09	0.38	0.19	4.17
	Zinc				<0.01		<0.01	0.06	0.47	0.07	0.02	0.12	0.18	0.92
Study Area 4	Arsenic				<0.01		<0.01	0.01	0.06	<0.01	0.33			0.40
	Lead				<0.01		<0.01	0.07	0.32	<0.01	0.08			0.47
	Mercury				<0.01		<0.01	0.08	0.38	0.06	3.33			3.85
	Zinc				<0.01		<0.01	0.06	0.47	0.07	0.02			0.62

Health Risk Characterisation
Hazard Quotient - Exposure Pathway and COPC

Adult

Exposure Pathway	COPC	Ingestion of drinking water - primary source	Incidental ingestion of drinking water secondary source	Incidental ingestion of water bathing / cleaning / washing & irrigation purposes	Incidental ingestion of recreation water swimming	Dermal contact with water - bathing / cleaning / washing & gardening activities	Dermal contact with recreation water - swimming	Ingestion of local fruit	Ingestion of local vegetables /grains	Ingestion of local meat and animal products	Ingestion of local fish	Ingestion of local crustaceans	Ingestion of local molluscs	Total HI
Study Area 1 (Tier 1)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01		0.03
	Lead	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.11	<0.01	0.02	<0.01		0.18
	Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.13	0.06	0.97	0.01		1.21
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.18	0.06	0.15	0.02		0.52
Study Area 1 (Tier 2)	Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	<0.01		0.03
	Lead	<0.01	0.10	<0.01	<0.01	<0.01	<0.01	0.04	0.12	0.02	0.02	<0.01		0.30
	Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.14	0.10	0.97	0.01		1.26
	Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	0.12	0.15	0.02		0.33
Study Area 3	Arsenic				<0.01		<0.01	<0.01	0.01	<0.01	0.17	<0.01	<0.01	0.18
	Lead				<0.01		<0.01	0.01	0.07	<0.01	0.04	<0.01	0.01	0.13
	Mercury				<0.01		<0.01	0.01	0.08	0.02	1.74	0.07	0.04	1.96
	Zinc				<0.01		<0.01	0.01	0.10	0.03	0.01	0.02	0.03	0.20
Study Area 4	Arsenic				<0.01		<0.01	<0.01	0.01	<0.01	0.18			0.20
	Lead				<0.01		<0.01	0.01	0.07	<0.01	0.04			0.12
	Mercury				<0.01		<0.01	0.01	0.08	0.02	1.87			1.99
	Zinc				<0.01		<0.01	0.01	0.10	0.03	<0.01			0.14

Appendix F - Key Management Measures

Project Environmental Management Plan - Key management assumptions

Management measures to address potential releases of contaminants to the environment are proposed for the construction and operation of the Project and will be contained within the Project Environmental Management Plan (EIS Attachment 3). The implementation of these measures has been assumed in the HHRA

The following is a summary of the relevant management measures that include, but are not limited to, the following:

- Implement the measures in the Project Environmental Management Plan and the Erosion and Sediment Control Plan.

Soils, sediment and erosion

- Manage Project-related disturbance and apply procedures to control access to undisturbed areas.
- Maintain hydraulic connectivity along linear infrastructure corridors for pipelines and roads (e.g. install culverts and drains where required).
- Install diversion channels prior to clearing in-stream habitat and divert flows around in-stream work areas.
- Decommission and revegetate temporary infrastructure footprints and access routes and restore disturbed primary drainage paths, where practicable.
- Limit the amount of sediment entering watercourses at crossings (e.g. bridges, roads and pipelines) by installing and maintaining appropriate sediment control measures that may include drainage diversion into surrounding vegetation, rip-rap aprons, sediment control ponds and sediment fences.
- Divert runoff from soil stockpiles and direct it to sediment ponds where practicable prior to release to the environment based on size of stockpile and environmental risk.
- Install erosion and sediment control structures to reduce fugitive sediment reporting to watercourses and surface water features.
- Maintain erosion and sediment control structures by:
  - Cleaning accumulated material from behind sediment fences and barriers, cut-off drains and diversion drains associated with temporary erosion control berms. Dispose of sediment appropriately.
  - Cleaning accumulated material from, and where required, dewatering sediment ponds. Dispose of sediment to an appropriate location. Treat water if required prior to discharge to meet PNG environment permit conditions.
  - Maintain sediment fences or barriers as required.

Waste waters, waste rock and leachate

- Capture and treat mine wastewater where necessary prior to discharge, to meet environment permit conditions.
- Treat sewage in accordance with environment permit conditions.
- Ensure water and wastewater treatment facilities are properly maintained.
- Actively manage PAF materials and control runoff and potential leachate from areas containing PAF material such as:
  - In situ treatment or reprocessing stockpiled material through the Watut Process Plant.
  - Diversion of clean surface water where required.
  - Interception of potential leachate from the site and applying appropriate treatment methods if required prior to discharge.
- Maintain drainage and seepage collection system on PAF cells.
- Monitor seepage from the waste rock dumps and surface side drains.

Air quality

- Maintain site access roads.
- Apply dust suppression in the vicinity of sensitive receptors (e.g., villages, schools, churches), as required during extended dry periods.

- Avoid burning cleared or standing vegetation, wherever practicable.
- Procure fit-for-purpose vehicles, plant and machinery, and regularly inspect and maintain in accordance with manufacturer recommendations.
- Cover the concentrate storage area and ship loading conveyors in order to contain concentrate dust and equip conveyors with rain/dust covers and suitable drip/spillage trays.
- Load the ship hatch through enclosed structures such as cement hatch hoppers.