Final Report

Volume 3
Plant and Wildlife Risk Assessment

Prepared for

P.T. FREEPORT INDONESIA
Affiliate of Freeport-McMoRan Copper & Gold

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The conduct of this assessment, as well as the review of findings, was supervised by the 19 members of the ERA Review Panel Team. The Panel was chaired by Professor Retno Soetaryono (SH, Msi), and the Panel was assisted by five members from the Universitas Indonesia. Their counsel, comments, and perspectives significantly enhanced the quality of the risk assessments. Team members are listed in the following two tables.

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ACRONYMS AND ABBREVIATIONS

ADA	Ajkwa Deposition Area
AERA	Aquatic Ecological Risk Assessment
AF	Absorbed Fraction
ANC	Acid-Neutralizing Capacity
ANCOVA	Analysis of Co-Variance
ANOVA	Analysis of Variance
ARD	Acid Rock Drainage
AUF	Area Use Factor
CDF	Cumulative Distribution Functions
CVI	Cover Value Index
CITES	Convention on International Trade in Endangered Species
COW	Contract of Work
CSIRO	Australia's Commonwealth Scientific and Industrial Research Organization
CSM	Conceptual Site Model
dbh	Diameter at Breast Height (1.3 m above the ground on a tree)
dw	Dry Weight
EC	Effect Concentration
EC_x	Estimated Concentration at which the Specified Parameter is Reduced x Percent
GBT	Indonesian Acronym for "East Ore Mountain"
GPS	Global Positioning System
ha	Hectare
HCI	Hydrologic Consultants, Inc.
HHRA	Human Health Risk Assessment
ITB	Institute of Technology – Bandung
IUCN	World Conservation Union
LIPI	Indonesian Institute of Sciences
LOAEC	Lowest Observed Adverse Effect Concentration
LOEC	Lowest Observed Effect Concentration
M21	Mile 21 Research Center
MPA	Maximum Acid-Generating Potential
MRT	Molecular Recognition Technology
MSL	Mean Sea Level
NOAEC	No Observed Adverse Effect Concentration
NOEC	No Observed Effect Concentration
NPP	Net Primary Production
NRC	National Research Council

ACRONYMS AND ABBREVIATIONS (continued)

ORNL	Oak Ridge National Laboratory
ppm	Part(s) per Million
ppt	Part(s) per Thousand
PTFI	PT Freeport Indonesia
PTHP	PT Hatfindo Prima
P&WERA	Plant and Wildlife Ecological Risk Assessment
RD	Relative Density
RDom	Relative Dominance
SLRA	Screening-Level Risk Assessment
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
95 UCL	95% Upper Confidence Limit of the Population
UNCEN	University Cendrawasih
US EPA	United States Environmental Protection Agency
w wt	Wet Weight

EXECUTIVE SUMMARY

This volume of the Risk Assessment for the PT Freeport Contract of Work (COW) Area assessed current and future potential risks to plant and wildlife resources arising from the tailings management system. The objective of this risk assessment is to evaluate potential risks from tailings in terrestrial and estuarine ecosystems from the mine to the sea. The terrestrial wildlife considered are all non-aquatic animals (in other words, air breathers), and plants assessed include all species except for algae or other purely aquatic forms. Potential risks to aquatic life are considered in the Aquatic Ecological Risk Assessment report. The assessment area covered the jungle ecosystem alongside the modified Ajkwa Deposition Area (the ADA) below the Otomona Bridge, the freshwater *Sago* and *Nypa* swamps outside of the middle modified ADA, and the mangrove and estuarine ecosystem outside of the lower modified ADA, from the brackish water areas to the Arafura Sea. However, wildlife that immigrate into the ADA to feed on cultivated plants, natural vegetation and animals inside the ADA also were considered.

JUNGLE ECOSYSTEM

The potential short- and long-term effects of tailings deposited in the modified ADA were assessed in relation to the jungle plant and wildlife communities. Pure tailings are nutrient-poor, possess concentrations of copper that could potentially affect some plants, and have poor water-holding capacity. Some plants do not germinate or grow well on pure tailings. However, plant bioassays conducted in support of this risk assessment showed that metals are not limiting plant germination and growth. The significant increases in germination following addition of only 10 percent forest soil to tailings shows that nutrient limitation and grain size are the primary inhibitors of successful plant growth. Within 5 years, significant revegetation will occur on tailings, although the species composition will differ from the mature jungle. It is likely that native species will eventually reinvade such an area, with development of a mature forest possible over a 20- to 30-year timeframe, without intervention. The rate at which this would occur is proportional to the size of the area affected, as large open areas have less of a seed bank available for natural reinvasion. PT Freeport is actively investigating reclamation of tailings in the ADA where tailings have been deposited under permit, in order to enhance these natural processes. Addition of compost results in at least a 10-fold increase in plant growth.

Some native plants and introduced agricultural crops will grow and take up a limited amount of metals from soil tailings mixtures. In terms of risk potential, residues of aluminum, arsenic, and copper are notable. Copper uptake in plants does not occur at concentrations sufficient to pose a risk to herbivorous animals. However, aluminum and arsenic can be sufficiently elevated in cultured cassava leaves, Chinese cabbage, and water-spinach to pose a risk to animals (e.g., pigs, cuscus) if the animals fed exclusively on these leafy plants in gardens grown on tailings-amended soil or compost.

EXECUTIVE SUMMARY (continued)

Among naturally occurring plants that have been growing on tailings-affected areas, only fern leaves (arsenic) and sweet potato leaves (aluminum) exceed the tolerances of plant-eating wildlife. Only soybean and figs had sufficient aluminum to pose a potential risk to mammals if they consumed them exclusively. Small insectivorous birds and bats that have localized feeding areas may have a slightly elevated potential risk of reproductive impairment from the aluminum contained in foliar insects from all areas; this is a background risk found throughout the study area that is unrelated to tailings. Based on the above, large-scale reclamation of the ADA or other areas that receive tailings should be done with plant species that do not concentrate metals to levels of concern.

MANGROVE ECOSYSTEM

The estuary at the mouth of the Ajkwa River system has been receiving tailings for 29 years, with increasing inputs expected in the future. Concern about the long-term viability of the ecosystem has focused on potential loss of trees due to sedimentation and smothering of the root systems and changes in aquatic life that might affect the food web as well as ecosystem functions such as decomposition.

Studies conducted over the past 2 years have shown that the tailings have had negligible effects to date on the mangrove trees and other plants. Floral diversity is similar to what would be expected based on community diversity indices and comparisons with other similar estuaries. Results of floristic composition studies suggest that the Ajkwa River estuary within the lower ADA remains a well established, late successional stage mangrove forest despite the influx of tailings. Mangrove colonizing species (*Avicennia* sp. and *Sonneratia* sp.) are able to vegetate newly formed islands that contain significant amounts of tailings. Seedlings propagate and grow at normal rates in tailings-containing sediments within the Ajkwa River estuary. Most crab species appear largely unaffected by the tailings, which is important as crabs contribute significantly to decomposition and carbon cycling within the estuarine ecosystem. All crab feeding guilds (detritus feeders, microalgae feeders, leaf litter feeders, etc.) are present on newly formed, tailings-containing islands. Decomposition rates of plants, as measured by litter fall comparisons, do not appear to be affected by tailings. Certain mollusks (specifically select snail species) appear to be sensitive to the tailings and are either reduced in numbers or absent from areas that have received tailings.

Despite the lack of direct effects of the tailings to mangrove trees, it is likely that some species of mangroves would be affected by increased rates of sedimentation. Species that are present in the well established mangrove forests, such as *Bruguiera* and *Rhizophora* sp., are unable to quickly grow new roots when buried by tailings. Approximately 100 mm of tailings will be sufficient to cover 50 percent of the roots of these species; 200 mm will cover 90 percent of the roots, and all roots will be covered by 300 mm of tailings. Colonizing species such as *Avicennia* and *Sonneratia* sp. have much

EXECUTIVE SUMMARY (continued)

shorter roots, with 50 percent under 50 mm tall and 90 percent under 100 mm. However, they are able to grow their roots rapidly out of the sediment, even when over 90 percent of them are covered. Therefore, as sediment continues to build up in the upper portions of the estuary, the well established, late successional stage ecosystem trees (including *Rhizophora* with its distinctive buttress roots and *Bruguiera* sp.) may be affected, and replaced by colonizing species.

The pattern of this change in mangrove tree species will depend upon how sediments deposit within the estuary channels. Measurements during 2000 indicated that increased tailings discharge rates will result in a build-up of sediment in walls alongside the channels, with significantly less deposition inland. Within about 500 m inland from the channel, deposition rates are quite low. Thus, inland trees may not be affected by sedimentation. In fact, predicted rates of inland sedimentation have not been observed during the past year of increased tailings input. However, it must be kept in mind that mangrove trees require tidal inundation and brackish water. A quantitative model of the Ajkwa River estuary developed by the Institute of Technology – Bandung (ITB) predicts filling in and drying up of upper mangrove areas in 2002 and 2003. By the year 2004, about 24 percent of the mangrove area is predicted to be above the high water line and, therefore, unable to support mangrove species. However, ITB's models also predict the build-up of sediment along the outer fringe of the estuary, and it is highly likely that new tailings islands will be formed. These are areas that will be vegetated by the rapid-growing, colonizing mangrove species, as is currently observed in the lower ADA (Ajkwa Estuary). Freshwater trees such as *Sago* and *Nypa* palms may revegetate areas that fill in above the high water mark. This area occupies the inland fringe of the estuary and is subject to freshwater inundation.

Mangrove saplings do not take up sufficient amounts of copper or other metals to pose a risk to wildlife inhabiting the ecosystem. Aluminum and copper were 2 of 12 elements measured in polychaetes that may pose potential risk to shorebirds like plovers, assuming they fed exclusively on these species and 100% of the copper was bioavailable. Potential risks may extend to mammalian omnivores (e.g., rats), assuming 10% of their diet consisted of shorebirds that had been feeding exclusively on these polychaetes. Because the potential risks are based on several conservative assumptions, their actual risk likely is minimal. Similarly, although there is some indication that select mollusks (certain snails) may decline in numbers and that aquatic life diversity may change within the modified ADA, sufficient prey biomass is likely to be present to maintain the naturally diverse community of wild birds and mammals within the ecosystem. Furthermore, any potential risks to wildlife from metals in tailings are likely to be small compared to other stresses in the COW. Recent surveys of crocodiles, for example, have shown that juveniles and young-of-the-year are present in the COW, but very few adults are found. This suggests that reproduction is not impaired but that adult survival has been affected by some stressor (e.g., hunting).

EXECUTIVE SUMMARY (continued)

CONCLUSIONS

Some of the fine tailings are moving into the lower ADA, which includes a section of the mangrove estuary, while depositing the heavier fractions in the upper ADA. Historic depositional areas outside the ADA (e.g., the Kali Kopi area prior to levee construction) have revegetated naturally. Vegetable gardens grown on tailings-containing soil or compost can pose potential risk to some wildlife (e.g., pigs, cuscus) that feed exclusively on leafy vegetables such as cabbage or cassava leaves.

Within the mangrove estuary of the lower ADA, species composition of the trees will shift over time, if tailings deposition maintains its current pattern. Invertebrate-feeding wildlife may be at some risk within the estuary, but such risks appear minimal considering home range and opportunistic feeding habits of the wildlife, and copper bioavailability. Mangrove trees that receive more than 100 mm of tailings per year are at highest potential risk. Newly formed islands or other tailings accretions can be colonized rapidly by mangrove seedlings. They also will fill in any of the central areas where trees are smothered, as is currently observed in this area. Areas of accretion that remain above the high tide level may become freshwater swamps, dominated by *Nypa* and/or *Sago* palms and associated plants.

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ATTACHMENT

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List of Data Reports

1

Tier 2 Plant Metal Uptake Study Data Report and Screening Assessment. Parametrix Inc., Kirkland, WA. 222 pg. + attachments. 2002

Affiliations of Authors:

Parametrix, Inc.

Study Description:

The Plant Metal Uptake Study was conducted to evaluate the potential effects of tailings on humans, wildlife and plants within and near the ADA. The two evaluations described in this data report were designed to:

(1) evaluate metals concentrations in cultivated plants used for human food and potentially for wildlife food

(2) evaluate metal concentrations in human use food plants and wildlife use food plants collected within the project area.

Metal concentrations were measured and uptake equations were developed for each metal and plant combination.

2

Analysis of Future Metal Concentrations in Tailings and Tailings-Affected Environmental Media. PTFI and Parametrix. 2001.

Affiliation of Authors:

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Study Description:

A data report prepared by Parametrix. It summarizes the methods used to estimate future tailings concentrations in environmental media. The Parametrix team conducted a comparative analysis of current tailings characteristics with those of future tailings projected to be discharged between 2014 and 2035. The characteristics of these future tailings were based on milling of cores extracted by PTFI from portions of the ore body to be mined during this period. Column leach tests with these tailings were also conducted to estimate geochemical behavior. Statistical comparisons of the current and future tailings concentrations served as the basis for predicting changes in concentrations of tailings substances in environmental media in the highlands, lowlands, and estuary. Media considered include surface water, groundwater, deposited tailings, and dust.

3

Mangrove colonization and associated macrofauna of Ajkwa and Kamora Islands. Parametrix Inc, Corvallis, OR. 72 pg. + attachments. 2002

Affiliations of Authors:

Parametrix, Inc.

Study Description:

This report describes studies designed to gain information about the structure and composition of mangrove communities colonizing newly formed islands containing tailings (Ajkwa island) and non-tailings areas (Kamora island). Study elements included vegetation and community descriptions, sampling of sediment and associated mangrove plant tissue, and mangrove macrofaunal benthic communities in the developing mangrove communities. Plant metal uptake was determined using the sediment and mangrove tissue data for each mangrove species sampled on each island.

4

Sedimentation and bathymetry data for the Ajkwa, Tipoeka and Kamora Estuaries. Parametrix Inc, Corvallis, OR. 21 pg.

Affiliations of Authors:

Parametrix, Inc., P.T Puri and PTFI

Study Description:

This report details ongoing long-term data collection of sediment elevations by P.T. Puri and PTFI personnel along transects in the Ajkwa, Tipoeka, and Kamora estuaries. It also presents bathymetric data for the Ajkwa River that was measured by P.T. Puri personnel at three different times: July 2000, December 2000 and March 2001. These data were used to calculate current sedimentation rates in the estuaries.

5

Plant-Metal Uptake Study: Plant Bioassay. Parametrix Inc, Kirkland, WA. 96 pg. 2001

Affiliations of Authors:

Parametrix, Inc.

Study Description:

This data report describes a study designed to estimate uptake of metals by plants and growth rates for plants grown in soils containing tailings. The objective was to evaluate the effects of metal concentrations, organic matter, nutrients and tailings texture on metal uptake and resultant plant tissue residues by short growth cycle plant species (human use food items) grown in compost and native soil-amended and non-amended tailings from the ADA. Germination and plant growth were measured along with metal concentrations in the plant tissues.

6

Plant community: terrestrial plant recolonization. Parametrix Inc, Corvallis, OR. 26 pg. 2002

Affiliations of Authors:

Parametrix, Inc.

Study Description:

This report discusses the results of a study conducted in 2000 designed to gain information about potential effects of tailings deposition on the composition of terrestrial plant communities that recolonized the areas after they received tailings. The numbers and type of rainforest plants were compared for study sites near MP 21, one within the Kali Kopi former sheetflow area, and one at the Nawaripi resettlement village.

7

Composition and Production of Mangrove Leaf Litter in the Ajkwa and Tipoeka Estuaries. Parametrix Inc, Corvallis, OR. 53 pg. 2002

Affiliations of Authors:

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Study Description:

This study sought to determine if the rates of litterfall and litter layer production in mangrove forests in the Ajkwa estuary differed from those of reference forests (the Tipoeka estuary area). Litter was collected from 2000 to 2001, sorted, and weighed. Mangrove species composition also was measured along transects and compared.

8

Mangrove seedling germination and growth preliminary data report. Parametrix Inc, Corvallis, OR. 22 pg. + attachments. 2002

Affiliations of Authors:

Parametrix, Inc.

Study Description:

This study examined the ability of mangrove species seedlings to germinate and grow on sediments with tailings. A potted plant study was conducted from 2000 -2001 using propagules from two species of mangroves (*Bruguiera gymnorhiza* and *Rhizophora apiculata*) collected from the Ajkwa and reference estuaries. Two *in situ* mangrove nurseries were established in the Ajkwa and Tipoeka estuaries, and the propagules from both areas were raised in sediments from each estuary. Germination success and subsequent seedling growth were measured along with the number of branches.

9

Mangrove acute and sub-lethal effects: aerial root growth. Parametrix Inc, Corvallis, OR. 52 pg. + attachments. 2001

Affiliations of Authors:

[1] Parametrix, Inc.

[2] Joanna Ellison, University of Tasmania

Study Description:

This study assessed rates of mangrove aerial root growth in the Ajkwa, Tipoeka and Kamora estuaries. In addition, it measured root growth in response to partial or total sedimentation of the roots. Aerial root responses to sedimentation were compared for colonizing and slow-growing inland mangrove species. Both acute and sublethal responses to sedimentation were evaluated.

10

Calculation of wildlife risk quotients for the wildlife detailed risk assessment. Parametrix Inc, Corvallis, OR. 36 pg. 2002

Affiliations of Authors:

Parametrix, Inc.

Study Description:

This report describes the methods used to estimate potential exposure of wildlife animals in the terrestrial and mangrove ecosystems to metals from the environment. Data from the plant and wildlife and aquatic ecological risk assessments were used. Estimates of potential exposure were compared against toxicological threshold values for various local indicator species to develop conservative estimates of potential risk, based on risk quotients. These quotients also were used to screen out exposure pathways that pose negligible risk. Pathways posing potential risk were examined further using probability distributions.