

## Appendix 1a: Technical Notes and Data Sources

This appendix is intended to be used as a supplement to Appendix 1 in the report *Mining and Critical Ecosystems: Mapping the Risks*. Methodological details have been organized by chapter and map number in the report.

### Data sources for Mining and Critical Ecosystems Maps

Map No.	Sources	Contact
Mine location (Global maps)	InfoMine, 2003, "Mining Data," InfoMine. All Rights Reserved	Rod Young ( <a href="mailto:young@infomine.com">young@infomine.com</a> )
Mine location (PNG maps)	Government of Papua New Guinea, Department of Mining, 2003	Government of Papua New Guinea, Department of Mining, Private Mail Bag, Port Moresby
Mine location (Philippines maps)	Government of the Philippines-Mines and Geosciences Bureau (MGB)- Department of Environment and Natural Resources (DENR), 2003, <a href="http://www.mbg.gov.ph">http://www.mbg.gov.ph</a>	Leo Jasareno, Chief Engineer, Mining Tenement Management Division ( <a href="mailto:mgbcentral@mines-denr.ph">mgbcentral@mines-denr.ph</a> ).
Map 1	<b>WWF Ecoregions:</b> World Wildlife Fund, "Global 200 Ecoregions," Washington, DC <b>Human Footprint:</b> E. Sanderson et al. (2002) <b>CI Hotspots:</b> Mittermeier et al., (1999); Conservation International (2001) "Biodiversity Hotspots," Conservation International: Washington, DC <b>Endemic Bird Areas:</b> Stattersfield et al., (1998) <b>Frontier Forests:</b> Bryant et al. (1997)	For frontier forests: Susan Minnemeyer, <a href="mailto:susanm@wri.org">susanm@wri.org</a>
Map 2	<b>Forest cover:</b> Government of Papua New Guinea, National Forest Authority "Forest Management Inventory System (FIMS), GoPNG: Port Moresby <b>Roads:</b> National Mapping Bureau, PO Box 5665, Boroko, NCD, Papua New Guinea <b>Villages:</b> Government of Papua New Guinea (2002), "Census 2000," GoPNG: Port Moresby	<b>Forests:</b> National Forest Authority, PO Box 5055, Boroko, NCD, Papua New Guinea <b>Roads:</b> National Mapping Bureau, PO Box 5665, Boroko, NCD, Papua New Guinea <b>Villages:</b> National Statistical Office, PO Box 337 Waigani
Map 3	<b>Protected Areas:</b> National Integrated Protected Areas System (NIPAS)- Protected Areas and Wildlife Bureau (DENR-PAWB), ( <a href="http://www.pawb.gov.ph">http://www.pawb.gov.ph</a> ); Forest Management Bureau (DENR-FMB) ( <a href="http://www.fmb.gov.ph">http://www.fmb.gov.ph</a> ); UNESCO World Heritage Sites <b>Forest Cover:</b> Data interpreted from SPOT 1987-88 images by the Swedish Space Corporation, published by National Mapping and Resource Information Administration (NAMRIA) ( <a href="http://www.namria.gov.ph">http://www.namria.gov.ph</a> ), 1988, Source	<b>Protected Areas:</b> Wilfrido S. Pollisco, Director ( <a href="mailto:director@pawb.gov.ph">director@pawb.gov.ph</a> ) <b>Biological Value:</b> Dr. Perry Ong, Science Director ( <a href="mailto:cimanila@csi.com.ph">cimanila@csi.com.ph</a> ).

	data are at a 1:50,000 resolution <b>Biological Value:</b> Ong et al. (2002)	
Map 4	Revenga et al. (2002)	Carmen Revenga, <a href="mailto:carmenr@wri.org">carmenr@wri.org</a>
Maps 5, 6	<b>Watersheds:</b> Presidential Task Force on Water Resources Development and Management (PTFWR), 1988 <b>Evapotranspiration:</b> M.J. Waterloo et al. (1999); Wu et al. (1993); J. Schellekens et al. (2000) <b>Water Demand:</b> Government of the Philippines—National Irrigation Administration (NIA) ( <a href="http://www.nia.gov.ph">http://www.nia.gov.ph</a> ); Philippine Population Census 2000—National Statistics Office (NSO) ( <a href="http://www.census.gov.ph">http://www.census.gov.ph</a> ); Döll et al. (2000) <b>Precipitation:</b> Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)—Department of Science and Technology (DOST) ( <a href="http://www.pagasa.dost.gov.ph">http://www.pagasa.dost.gov.ph</a> ), <i>Climate of the Philippines</i> , 1999.	<b>Watersheds:</b> Government of the Philippines—Department of Environment and Natural Resources (DENR), ( <a href="http://www1.denr.gov.ph">http://www1.denr.gov.ph</a> ). <b>Water Demand:</b> Carmelita N. Ericta, Administrator (C.Ericta@mail.census.gov.ph)
Map 7	<b>Education:</b> Barro and Lee (2000) <b>Literacy:</b> UNESCO (2002) <b>Income:</b> World Bank (2003)	
Map 8	<b>Welfare:</b> UNDP (2002) <b>Income:</b> DOF (1999) <b>Education:</b> Census data collected in 1995, Public Use Files by the National Statistics Office (NSO) <a href="http://www.census.gov.ph">http://www.census.gov.ph</a>	<b>Education:</b> Carmelita Ericta, Administrator (C.Ericta@mail.census.gov.ph)
Map 9	<b>Roads:</b> National Mapping Bureau (NMB), PO Box 5665, Boroko, NCD, Papua New Guinea <b>Villages:</b> Government of Papua New Guinea (2002), “Census 2000,” GoPNG: Port Moresby.	<b>Roads:</b> National Mapping Bureau (NMB), PO Box 5665, Boroko, NCD, Papua New Guinea <b>Villages:</b> National Statistical Office, PO Box 337 Waigani.
Map 10	Giardini et al. (2000)	Available online at: <a href="http://seismo.ethz.ch/gshap/global/global.html">http://seismo.ethz.ch/gshap/global/global.html</a> .
Map 11	<b>Precipitation:</b> Global Historical Climatology Network (GHCN), <i>Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950 - 1999)</i> (Version 1.02); Legates and Wilmott (1990) <b>Evaporation:</b> NOAA, NCEP-NCAR CDAS-1 “Monthly diagnostic data set,” last updated August 2003.	<b>Precipitation:</b> Center for Climatic Research Department of Geography University of Delaware Newark, DE 19716 (302) 831-2294 or <a href="mailto:kenjisan@udel.edu">kenjisan@udel.edu</a>
Map 12	<b>Earthquake Hazard:</b> Philippine Institute of Volcanology and Seismology (PHILVOLCS)-Department of Science and Technology (DOST) (2000) “Minimum Probabilistic Horizontal Peak Ground Acceleration (HGPA)” <b>Geology:</b> Mines and Geosciences Bureau	<b>Earthquake Hazard:</b> <a href="http://www.phivolcs.dost.gov.ph">http://www.phivolcs.dost.gov.ph</a> <b>Geology:</b> <a href="mailto:mgbcentral@mines-denr.ph">mgbcentral@mines-denr.ph</a>

	(MGB)-Department of Environment and Natural Resources (DENR), 1986, "Geology of the Philippines.", ( <a href="http://www.mgb.gov.ph">http://www.mgb.gov.ph</a> ) <b>Soil Data:</b> Derived from Bureau of Soil and Water Management—Department of Agriculture (DA), 1993, "Soil Map of the Philippines," ( <a href="http://bswm.da.gov.ph">http://bswm.da.gov.ph</a> ).	
Maps 13, 14	Kaufmann et al. (1999a), (1999b), (2002)	

### Chapter 1: Introduction and Background

Figure 1: Share of Production by Global Region for Selected Minerals

	Asia-Pacific	Latin America	Africa	Europe	Canada/U.S.
Bauxite	53	9	11	9	26
Nickel	37	17	0.1	24	32
Copper	22	43	4	14	59
Gold	31	15	24	11	34
Diamonds	19	0.6	58	19	3

Source: USGS, 2000

Figure 2: Entries in Mine Database by Production Status

Type of Mine	Number	% of Total
Unknown	196	4.45
Past Producer	662	15
Raw Prospect	868	19.7
Exploration	2207	50.1
Producer	471	10.6
<b>Total</b>	<b>4404</b>	<b>100</b>

Source: InfoMine, 2003

Figure 3: Approved Exploration and Mining Permits in the Philippines, 1990-2002

Year	Exploration Permits	Mining Permits
1990	NA	1
1991	NA	5
1992	NA	8
1993	NA	4
1994	NA	10
1995	4	7
1996	4	28
1997	39	43
1998	2	1
1999	5	45
2000	10	18
2001	2	2
2002	8	15

Source: MGB, 2003.

Figure 4: Approved Exploration Licenses in Papua New Guinea, 1980-2003

Year	Exploration Licences
1980	3
1981	0
1982	0
1983	1
1984	2
1985	3
1986	3
1987	0
1988	1
1989	1
1990	0
1991	1
1992	8
1993	3
1994	5
1995	0
1996	2
1997	6
1998	0
1999	2
2000	7
2001	11
2002	5
2003*	15

\*Estimate

Source: GoPNG, 2001; GoPNG, 2003

### **Chapter 3: Ecologically Vulnerable Areas**

#### *Map 2: Intact Areas of High Conservation Value*

Map 1 is a coarse depiction of the relative condition (expressed as percent disturbed) of high conservation value ecosystems, stratified by size. High conservation value areas were identified by combining data layers on Global 200 Ecoregions, CI Hotspots, Endemic Bird Areas, and Frontier Forests. This aggregate layer was combined with the Human Footprint map developed by WCS and CIESIN to identify areas of high conservation value that remain relatively intact. The 10% or less disturbed layer was combined with the WWF ecoregions of the world map. Continuous blocks of intact areas were identified and classified by size.

A key advantage of using the human footprint analysis to depict ecosystem condition is that human influence was normalized according to biogeographic realms (e.g., Neotropical, North America, Afrotropical, etc), such that the human footprint of an area was compared to that of its biogeographic realm rather than to a global average. Unfortunately, the human footprint analysis overestimates the human footprint on the island of New Guinea, thus Map 2 underrepresents the overlap between mines and intact high conservation value areas in this part of the world.

#### *Map 3: Ecological Value in Papua New Guinea*

The PNG case study incorporates forest cover according to the PNG Government Forest Inventory and Mapping System (FIMS) database. Data are available at a scale of 1:50,000. "Fragile Forests" consist of the following forest types:

- n Open forest on plains and fans below 1000m: These forests are characterized by valuable tree species. Logging can create hydrological disturbances resulting in permanent inundation if the land is seasonally inundated for long periods.

- n Large to medium crowned forest on plains and fans: These forests are the most floristically rich in PNG and are threatened by road development, logging, mining, and agriculture. This forest type is considered a high conservation priority to protect habitat and plant diversity.
- n Small crowned forest with *Nothofagus*: These rare forests are found in lower montane areas (1000-3000m). As the habitat is generally very wet, logging tends to cause significant damage to soils.
- n Low altitude small crowned forest with *Nothofagus*: These forests regenerate very slowly and often occur on karst landscapes. They are considered a refuge for many endemic vertebrate species. Large stands should not be logged.
- n Small crowned forest with *Araucaria*: Occurring at sub-montane altitudes (above 1000 m.), these forests are important for habitat diversity in PNG and internationally. Dense stands of *Araucaria* should not be logged.
- n Small-crowned forest with conifers: These forests are found in cold and extremely wet climate conditions, inhibiting regeneration. Logging would result in excessive soil damage.
- n Very small crowned forest: Due to high moisture, these forests are susceptible to soil damage if logged.
- n Dry evergreen forest: These forests are of high ecological value and are known to house many endemic species. Logging increases vulnerability to fire, causing degradation and conversion to woodlands and savannas. The potential for regeneration after logging is very low.
- n Woodland: The presence of woodlands indicates that fire damage is frequent and that soils are poor. Logging increases the likelihood that any remaining forest will be converted to savanna. Dry Evergreen Forest in a mosaic with woodland or Savanna/Scrub should be protected.
- n Savanna types: Savanna vegetation occurs on soils of low and very low soil fertility, is prone to fire damage, and is important for ecological and stream protection.
- n Swamp forest types: Logging results in hydrological disturbances that reduce the chances of successful regeneration. Swamp forests should not be logged with the exception of *Terminalia brassii*.
- n Riverine successions with *Eucalyptus deglupta*: These forests are only found on New Britain and are disappearing. Logging is likely to cause stream bank erosion. Regeneration of these forests after logging is unlikely.
- n Riverine successions with *Terminalia brassii*: These forests are important for maintaining habitat diversity and are only found on New Ireland and Bougainville. Logging will cause stream bank erosion.
- n Volcanic successions: Logging would involve clear felling as the forest is usually an even-aged stand. Due to steep slopes, such practices would increase the probability of landslides.
- n Littoral forest: These forests have high biodiversity value and are important for coastal protection.
- n Mangroves: Mangrove logging is prohibited by the PNG logging code of practice.

The relative condition (intact/fragmented) of all forest types was determined based on overlays of roads and settlements. Roads were buffered by 2 kilometers and settlements by 5 kilometers. Villages located 5 kilometers from another settlement were deemed to be isolated and were excluded from the analysis.

Forests subject to logging have not been taken into account in this analysis. This does not imply that logging has not degraded forests in Papua New Guinea, but rather that most logged forests have not been converted to other non-forest land uses.

*Map 4: Ecological Value in the Philippines*

Areas of high vulnerability correspond to officially designated protected areas, closed canopy forests, and mangroves. Areas of medium vulnerability correspond to secondary forests, and areas categorized by conservation priority setting exercises (PBCPP) as “extremely high urgent” and “extremely high critical.” All other areas were classified as “low vulnerability.” Forest cover data are based on SPOT satellite imagery from 1987, modeled to 1995 to account for changes in forest cover. More recent satellite-based assessments of forest cover are not available for the Philippines.

*Map 5: Mining in Stressed Watersheds*

Watershed stress was defined according to the PAGE water scarcity model developed by the University of New Hampshire in collaboration with the World Resources Institute (see Revenga et al., 2000). The model combines a runoff model with population projections developed using CIESIN data with WRI projections. The UNH runoff model is at 0.5 degree grid resolution and combines available discharge monitoring data with a water balance model based on climate variables (i.e., air temperature and precipitation). The population projections developed by WRI are based on 1990 and 1995 CIESIN data, which were converted to a 2.5 minute grid. The population data are fairly fine-scale, as they have been disaggregated into 120,000 administrative units. WRI developed projections for 2025 based on an exponential growth model, which uses the UN low growth rate and average national population growth rate as limiting factors.

This dataset does not take into account the effects of pollution, climate change, impoundment, and evaporation of water supply. Thus, the data likely overestimate future availability of water per capita. In addition, the PAGE analysis assumes constant water supply, with benchmarks of available water to identify watersheds that may experience water shortages. The estimates of water demand are considered to be conservative as they assume that up to 50% of water can be used for human consumption (Revenga et al., 2000). Furthermore, all water demands (domestic, agricultural, and industry) have been combined and assigned a per capita value (1 or 1.7 megalitres/year). In fact, as pointed out by Alcamo et al. (1997), the intensity of water use varies according to income, with lower-income countries consuming less water per capita than high-income countries.

*Map 6: Protected Watersheds in the Philippines*

The map identifies watersheds and groundwater resources recognized by the Philippine government as vulnerable to development activities. Important groundwater resource areas are identified and categorized by the Mines and Geosciences Bureau (1997) into low, medium, and high risk ratings based on aquifer definitions. There is no certainty that the location of a groundwater catchment will be consistent with an overlying surface water catchment, particularly in the case of confined aquifers and karstic landscapes. Therefore, the groundwater resource layer used in this study is treated independently from the watershed layer.

Groundwater availability is divided as follows:

Code	Symbol	Description (Groundwater flow in Series 1 rocks is intergranular)
I-A	592	Extensive and highly productive aquifers.
I-B	621	Fairly extensive and productive aquifers.
I-C	617	Local and less productive aquifers.
(Groundwater flow in Series 2 rocks is dominated by fractures and solution pathways)		
II-A	9	Fairly extensive and productive aquifers with high potential recharge.

II-B	10	Fairly to less extensive and productive aquifers with low to moderate recharge.
Lake	15	Open surface water bodies.
		(Groundwater flow in Series 3 rocks is generally considered insignificant or insufficient for any production purposes.)
III-A	115	Rocks with limited potential, low to moderate permeability.
III-B	81	Rocks without any known significant groundwater obtainable through drilled wells, largely untested.

On this basis, highly vulnerable groundwater zones include regions classified as IA, IB & IIA because pollution from mining and changes in landform would significantly affect groundwater resources in these zones. Moderately vulnerable groundwater zones include regions classified as IC & IIB. Groundwater zones with low vulnerability include regions classified as IIIA & IIIB. Lakes are automatically considered exempt from mining. Source data are at a 1:250,000 scale.

*Map 7: Mining in Stressed Watersheds in the Philippines*

Stressed watersheds were defined by comparing water availability to demand, similar to the methodology used by the University of Kassel's WaterGAP project (Alcamo et al., 2000). WaterGAP consists of a hydrological model that computes water use and water availability for 1,162 watersheds covering most of the world's land mass. Four assumptions based on population, industry, livestock and irrigation are used to determine water demand. Based on these assumptions, WaterGAP includes scenarios for projected water use in 2025 and 2075. A water scarcity index was then developed based on available water per watershed and water availability per capita (Alcamo et al., 1997).

The Philippines case study of the Mining and Critical Ecosystems project estimated water availability based on a measure of effective rainfall (calculated according to a theoretical model that takes into account rainfall intensity and its relationship to the speed of runoff) and a measure of evapotranspiration, adjusted for land cover types. The primary unit of analysis for this map is a sub-basin, while the global analysis (Map 5) used a coarser-scale watershed basin. Source data were at a 1:250,000 scale.

Water demand in the Philippines was calculated by combining estimates of water use from irrigation and domestic use requirements. This combined demand estimate was compared to estimated available water from runoff to determine a stress ratio by watershed. Alcamo et al. (2000) define highly stressed watersheds as those in which demand exceeds water availability by 40 percent. In the Philippines, data for some water uses (industry, livestock, fisheries) were not available, accounting for at least an additional 10 percent of water demand. For this reason, high stress in the Philippine case study was defined as a demand exceeding water availability by 36 percent. Medium stress has been defined as a demand to water availability ratio between 0.18 and 0.36.

**Chapter 4: Mining and Vulnerable Communities**

*Figure 6: Change in Human Development Indices in Papua New Guinea's Mining Provinces, 1980-1996*

Province	School Enrollment (% change)	Life Expectancy (% change)	Decrease in Infant Mortality (% change)
Western	25.7	13.3	34.9
Central	24.2	9.5	11.9
Milne Bay	18.1	-7.5	-28
Enga	20.3	7.8	-19.8
New Ireland	11.6	7	-8.1
National Average	24.1	8.1	-1.4

Source: UNDP, 1999

*Map 7: Mining in Socially Vulnerable Areas*

The global indicator of capacity for informed decision-making incorporates measures of education attainment and income. Education attainment was measured by indicators of adult literacy, functional literacy, and tertiary education attainment. Adult literacy is defined as the percentage of people older than 15 years who can both read and write a short statement about their life. Functional literacy reflects a higher degree of understanding, but it has not been systematically measured at a global level. However, UNESCO considers completion of 4 years of education to be sufficient evidence in some cases of functional literacy (TFHES, 2000: 176). Thus functional literacy was estimated using data for the average number of years of education of a country’s population and tertiary education attainment rates. Countries where the average population had attained less than 4 years of education were scored low for functional literacy. Adult literacy rates from UNESCO were used in some cases where data were missing. A country with less than 50 percent adult literacy was automatically considered to have low education attainment.

Tertiary education attainment was used to separate countries with high education capacity from those that were scored “medium.” Tertiary education attainment reflects the proportion of the population that has attained (but not necessarily completed) some form of post-secondary education. A cutoff of 11.17 percent tertiary attainment was used for developed countries and 22.59 percent for developing countries. The cutoff used for developed countries represents the global average of tertiary education attainment in 2000 while the cutoff for developing countries reflects the average attainment of “advanced countries” (i.e., developed countries) as defined by Barro and Lee (2002). A higher cutoff was used for developing countries because the number of pre-college years and quality of education is often lower in these countries than in developed countries.

Rankings of capacity for informed decision-making were obtained by using World Bank income classification categories to adjust the education attainment rank. The resulting low, medium, and high scores were derived as follows:

		Income		
		Low	Medium	High
Education Attainment	Low	Low	Low	Not possible
	Medium	Low	Medium	High
	High	Not Possible	High	High

The data used in the global analysis were only available at a national scale and do not take into consideration sub-national variation. The resulting indicator of capacity for informed decision-making is coarse and should be used with caution when combining it with point data, such as the location of mine operations. However, the indicator can be used to summarize general trends and it roughly corresponds to similar global indicators (e.g., UNDP’s Human Development Index).

*Map 8: Vulnerable Communities in the Philippines*

The indicator of capacity for informed decision-making in the Philippines is based on a summary of indices covering education, welfare, and peoples’ participation. Education was based on tertiary attainment and the secondary school graduate ratio, which has been found to be a suitable proxy for functional literacy (PDHR, 2002). Welfare was estimated based on the income index of the Human Development Report for the Philippines and results from an economic classification of local governments. Peoples’ participation is a reflection of membership in peoples’ organizations and non-governmental organizations, based on survey data. Municipalities in which more than 50 percent of the household are members in a Peoples’ Organization (PO) or Non-Governmental Organization (NGO) were considered to have high participation while low participation was assigned to households where only 25 percent of the population is a member of a PO/NGO. Membership in a PO/NGO does not directly reflect the degree to which members participate in civil society as it does not take into account active versus inactive members.

*Map 9: Vulnerable Communities in Papua New Guinea*

The indicator of capacity for informed decision-making in Papua New Guinea is based on a measure of remoteness, which was used as a proxy for the degree of community isolation. Other indicators of capacity

for informed decision-making (e.g., education and welfare) were not available at a sub-provincial scale; therefore, they were not incorporated in the analysis of vulnerable communities.

Village data from the 2000 census were combined with roads. Villages within 5 km of a road or within 5 km of one another were considered to be “accessed” and thus defined as having high capacity for informed decision-making. Villages located 5-10 km from a road or from each other were considered “moderately accessed” and thus defined as having medium capacity for informed decision-making, and those located more than 10 km from a road or from one another were considered to be remote (low capacity for informed decision-making). The distance parameters were based on the average distance a villager may travel on foot in a day. Ten km was deemed to be equal to one day’s travel, based on the rough terrain and poor condition of roads. Proximity to the coastline was treated in much the same way as roads, given that villagers living on the coast often use boats to reach one another.

## ***Chapter 5: Natural Hazards and Mining***

### *Map 10: Seismic Hazard*

Global seismicity was defined according to the Global Seismic Hazard map developed by the USGS (Giardini et al., 2000). The seismic hazard indicator used in the Mining and Critical Ecosystems framework does not consider risk from landslides or mass wasting. To some degree, earthquakes and landslides are linked; areas with high seismicity tend to result in slopes that are highly sheared, unstable and prone to erosion. Furthermore, mass erosion of such slopes contributes to sedimentation within rivers and downstream flooding. Although steep slopes and sharp breaks in slopes can be considered indicators for landslide and slope failure, the available elevation data were deemed too coarse to identify areas with potential for mass wasting.

### *Map 11: Areas Prone to Water Quality Problems (Weinert Index)*

To estimate areas where mines will face water quality challenges, the project used the Weinert N Weathering Index, which describes the weathering characteristics of an area (Weinert, 1964). The index ranges in value from 1 (predominance of chemical weathering) to 5 (predominance of physical weathering). Areas with low values (< 2.0) are characterized by wet, warm climates year round whereas those with high values (> 4.0) are predominantly dry. Areas in the moderate range (2.0-4.0) are characterized by seasonal high rainfall periods, which may pose water quality problems during peak rainfall months.

The index is calculated as follows:  $N = (12 * E_j) / P_a$

Where:

$E_j$  = Mean evaporation (in millimeters) for the warmest month, and

$P_a$  = Mean annual precipitation (in millimeters)

The original results of the global analysis returned low N values for areas north of 60 degrees latitude. This is likely due to the fact that areas in extreme northern and southern latitudes experience low evaporation due to extremely cold climates. For this reason, we masked areas north of 60 degrees N latitude in our analysis. Antarctica was excluded from all analyses. The evaporation data were available at a 1.875 degree resolution and the precipitation data were at a 0.5 degree resolution. The analysis was conducted at a 1-km resolution and is limited by the coarseness of the data.

The Weinert Index was developed to estimate the suitability of igneous rocks for road building in South Africa. To date, the index has not been applied outside of the African context and may not accurately reflect water quality problems in all parts of the world. The model does not take into account the stability of other rock types and their ancillary minerals. In addition, topography can affect monthly and annual precipitation resulting in inaccurate N values.

### *Map 12: Seismic Risk in the Philippines*

Seismic risk was defined for the Philippines using data on geology, soil type, horizontal peak ground acceleration, and building codes. Soils were divided according to four types of ground condition (rock, hard soil, medium soil, soft soil) based on Fukushima and Tanaka (1990). A ground type layer was

developed based on geology and soil type. Due to the lack of strong motion data for the Philippines, ground motion was determined according to an amplification factor as per the attenuation model developed for Japan in Fukushima and Tanaka (1990). Ground motion was then combined with horizontal peak ground acceleration (HPGA) maps available at a national scale for the Philippines (Thenhaus et al., 1994) to determine ground motion hazard. Earthquake hazard and soil source data were at 1:250,000 scale. Geology source data were at a 1:1,000,000 scale.

Government regulations in the Philippines require all tailings facilities to be built to withstand at least a 0.15g earthquake, which is estimated to occur at least once during the life of operation of the impoundment. A tailings facility may be required to withstand at least a 0.25g earthquake depending on the presence of local faults. On the basis of these regulations, seismic risk was determined as follows:

Low risk= HPGA values < 0.25g

Medium risk= HPGA values 0.25-0.4g

High risk= HPGA value > 0.4g

Qualitatively, seismic risk is defined by the following:

**High Risk** – On the basis of ground motion hazard, the integrity of tailings dams and associated infrastructure require design standards higher than the minimum government requirement and the standard set by the Philippine Building Code.

**Medium Risk** – On the basis of ground motion hazard, the integrity of tailings dams and associated infrastructure require design standards higher than the minimum government requirement.

**Low Risk** - Tailings dams and associated mining structures, if built following the government's minimum requirement, are expected to withstand risk posed by inherent natural seismicity.

## ***Chapter 6: Institutional Extenuating Factors***

### ***Maps 12-14***

Since the late 1990s, the World Bank Institute has rated governance in 175 countries according to an aggregated list of indicators. Based on a wide variety of available private and public governance surveys, the dataset groups the indicators according to “voice and accountability,” “political instability,” “regulatory burden,” “rule of law,” “control of corruption,” and “government effectiveness,” defined below (Kaufmann et al., 1999a, 1999b, 2002). The Mining and Critical Ecosystems project aggregated five of the six indicators developed by Kaufmann et al. (2002) by averaging the relative rank of countries according to each aggregate indicator. Regulatory burden was left out of the aggregated governance index. This indicator was deemed irrelevant for this study because it measures impediments to private sector investment.

- n *Voice and accountability*: The degree to which citizens in a country are able to participate in the selection of governments, including civil liberties, political rights, and independence of the media.
- n *Political instability and violence*: Perceptions of the likelihood that a government will be overthrown or destabilized by unconstitutional or violent means.
- n *Regulatory burden*: The degree to which “excessive” regulation results in market-unfriendly policies and impedes private investment, including price controls, inadequate bank supervision, and perceptions of excessive regulation in areas of foreign trade and business development.
- n *Government effectiveness*: The quality of public service provision, including the competence of civil servants, independence of civil service from political pressures, and the credibility of the government's commitment to policies.

- n *Rule of law*: The extent to which citizens and the government abide by the rules, including perceptions of the incidence of violent and non-violent crime, effectiveness of the judiciary, and enforceability of contracts.
- n *Graft*: The exercise of public power for private gain, based on perceptions of corruption as expressed by business.

Kaufmann et al. rank countries on a scale of -2.5 (poor) to 2.5 (good) for each aggregate indicator. Because the indicators are based on subjective measures, the numeric values assigned to each country cannot be meaningfully compared to one another, except in broad country groupings. The standard deviations tend to be large relative to the average value that defines performance for many countries represented in the aggregate indicators. To account for this we divided the dataset into four broad categories according to natural breaks in the data. These broad categories are consistent with the approach recommended by Kaufmann et al. (2002).

### Chapter 7: Financial Institutions Exposed to Environmental and Social Risks

Figure 7: Ecological Vulnerability in Papua New Guinea by Active Mine

Mine	Total Forest (% of concession)	Intact Forest (% of concession)	Fragile Forest (% of concession)	Non-Forest (% of concession)
Porgera	80.4	44.8	55.6	19.6
Ok Tedi	94.4	48.9	1.7	5.6
Misima	43.9	0	0	56.1
Lihir	51.2	0	0	48.8
Tolukuma	86.7	57	26.4	13.3
Kainantu	51.8	13.9	15.5	48.2

Source: Map 3

#### Overall Data Quality Assessment

Indicators developed for this report incorporated the best available data. The quality of the maps and indicators varies according to the resolution of the analysis. Variation amongst units of analysis is greatest at the global scale. For this reason, combining global-scale indicators with data on mine sites should be done for illustrative purposes only. Although this analysis can shed light on areas where vulnerabilities may be high, further fine-scale analysis is required to determine the degree to which these areas are exposed to risk.

The following table summarizes the limitations and the degree of confidence in the quality of the data estimated by the Mining and Critical Ecosystems Project Team.

#### Data Quality Assessment

Indicator	Limitations	Degree of Confidence
<b>Global</b>		
Ecological Value	? Coarse scale ? Under-estimate of New Guinea intactness ? Biased towards terrestrial ecosystems	Medium
Watershed Stress	? Underestimates demand from industry ? Assumes uniform water use between developing and developed countries	High
Capacity for Informed Decision-Making	? Unit of analysis (country) ? Uses aggregated income and education statistics that mask sub-national variations	Low
Seismicity	? Coarse scale	High

Water Quality	? Fails to capture potential water quality problems in Western U.S. ? Underestimates quality problems in mountains ? Coarse scale	Low
Governance	? Large margins of error ? Based on subjective surveys ? Unit of analysis (country)	Low
<b>Philippines</b>		
Ecological Value	? Based on expert opinion ? Likely overestimate of actual forest cover (based on 1987 satellite imagery)	Medium
Watershed Stress	? Underestimates demand from agriculture	High
Capacity for Informed Decision-Making	? Membership in civil society groups does not imply active participation	High
Moisture availability	? Coarse scale	Low
Seismicity	? Does not include slope ? Does not consider integrity of mine structures	High
<b>Papua New Guinea</b>		
Ecological Value	? Does not take into account the impact of logging in estimating intact and fragmented forests ? Not field checked	High
Capacity for Informed Decision-Making	? Based on distance parameter exclusively ? Not field checked	Medium
Seismicity	? Coarse scale	Low
Moisture availability	? Coarse scale	Low

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