

ANNEX D



**SUPPLEMENTAL INFORMATION
FOR IMPACTS
DISCUSSIONS**

ANNEX D-I

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; FLORA

ANALYSIS OF IMPACTS TO FLORA

DIRECT EFFECTS

Construction of the proposed mine and ancillary facilities would directly affect about 1,428 hectares through removal of vegetation, soil and subsoil. Of this total area, approximately 74 hectares would be removed from the Ajenjua Bepo Forest Reserve consisting of non-native cedrela plantations (19.1 hectares), cocoa (1.1 hectares), fallow (0.3 hectares) and degraded secondary forest (53.5 hectares). Approximate percentages of vegetation cover types in the 1,354 hectares outside of the Ajenjua Bepo Forest Reserve that would be disturbed by development of the mine and ancillary facilities are shown below:

- Oil palm (approximately 24 percent),
- Citrus (approximately 2 percent),
- Cedrela (approximately 2 percent),
- Cocoa (approximately 36 percent),
- Food crop (approximately 12 percent),
- Secondary forest (approximately 12 percent),
- Fallow (approximately 11 percent),
- Teak (less than 1 percent)
- Wetlands (less than 1 percent)
- Village (approximately 0.7 percent)

There would be no direct affects on the flora of the Mamang River Forest Reserve with the proposed action.

Trees of commercial value would be removed by mine development in the Ajenjua Bepo Forest Reserve in coordination with the Ghana Forestry Commission. Trees interspersed among crop fields and providing shade for cocoa plantations also would be removed outside of the forest reserve. Ghana Wildlife Society (2007) found that cocoa plantations often have trees of commercial value, providing shade for cocoa, which are listed as “Vulnerable” by IUCN.

The IUCN Red list identifies the following species of trees found in the Akyem Study Area as “Vulnerable”: *Albizia ferruginea*, *Entandrophragma angolese*, *E. cylindricum*, *Nauclea diderrichii*, *Nesogordonia papaverifera*, *Pterygota macrocarpa* and *Terminalia ivorensis*. These valuable timber species (Scarlet Star), subject to overharvesting in Ghana, would be removed in the Ajenjua Bepo Forest Reserve and on some cocoa plantations where they provide overstory shade. One seral Gold Star tree species, *Cussonia bancoensis*, would be affected by development of the Tailings Storage Facility. This species is not common in Ghana, but occurs in all forest zones and regenerates freely in many areas (Hawthorne 1995).

Most of the plants that would be removed by the mine and ancillary facilities are Pink Star or Green Star species. Pink Star species are common and widespread commercial species not currently under significant pressure from exploitation. Green star species are common and widespread in tropical Africa and of no conservation concern. Impacts on biodiversity would be long term and irreversible on the unreclaimed mine footprint, but there would be negligible effects on local and regional biodiversity if species of conservation concern remain

extant and viable in adjacent forest reserves, on land unaffected by mine development outside of forest reserves, and on land reclaimed to native species. Impacts on biodiversity would be long-term and irreversible on the unreclaimed mine pit footprint (approximately 79 hectares), but this would have a negligible effect on local and regional biodiversity.

During closure and decommissioning of the smaller eastern lobe of the mine pit, waste rock would be placed resulting in the development of approximately 19 hectares of arable land. In addition, the Company would place waste rock in approximately one half of the larger western mine pit which would bring the total reclaimed open pit area to approximately 70 hectares of arable land. The remaining portion of the larger western mine pit would not be revegetated; consequently, crop and timber production potential on this land would be permanently lost. A permanent loss of crop land would occur on sites where disturbed land would not be revegetated (i.e., part of the mine pit) or would have topography unsuitable for agricultural use (i.e., mine pit highwalls, parts of the waste rock and tailings storage facilities). It is expected the unreclaimed mine pit would fill with water and result in a lake.

Upon completion of mining, the waste rock and tailings storage facilities would have a layer of soil spread over exposed surfaces and revegetated; however, steep topography on portions of the waste rock disposal facilities and tailings impoundment may not be suitable for sustained agricultural activities because steep slopes would be subject to erosion and loss of soil necessary to support crop production or livestock grazing. Steep slopes of the waste rock disposal facilities and tailings impoundment may support tree growth with value for timber or other wood products.

Loss of cropland and other vegetation on revegetated areas would be a reversible impact that would last for the duration of mining and several years after mining. With successful reclamation, disturbed land would likely be capable of supporting crop production within three years of Project completion; however, little information exists concerning the long-term productivity of reclaimed mined lands in Ghana for crops and timber. Commercial timber stands would require considerably longer (more than 20 years) to re-establish.

Topsoil and other mine substrates would likely lose fertility during storage and be less productive than undisturbed soil. Supplying supplemental plant nutrients and organic material to reclaimed areas would likely be necessary to initiate recovery of a diverse and self-sustaining cover of vegetation. To determine if supplemental nutrients would be required to re-establish post-mining vegetation, testing for macro and micronutrients would be required prior to seeding and planting.

To restore crop and timber production potential on reclaimed land, establishment of locally adapted, nitrogen-fixing legumes would be a component of the initial revegetation mix of species. Salvage and replacement of topsoil and recontouring surface features to accommodate agricultural activities is specified in conceptual mitigation plans.

Construction of the 161 kV power line would follow the existing road from Nkawkaw to New Abirem. An existing right-of-way would need to be widened and tall trees removed to prevent them from falling on the power line. Loss of timber production potential on the cleared right-of-way would be long-term.

INDIRECT EFFECTS

Removal of vegetation from mine-related development and ancillary facilities would have indirect effects on vegetation locally as a result of increased human population density and associated demands for crop production. With removal of land from production and resettlement of affected villages to adjacent areas, local population densities would increase. Also, with construction and operation of the mine, more people would come to the area seeking jobs or would be employed at the mine. Site-specific and local reductions in crop land from mine-related development would increase demand for unaffected land outside of the mine disturbance area for crop production, charcoal and other natural amenities derived from plant communities.

With increased local demand for production of food and cash crops, fallow cycles would likely shorten, reducing the productivity of land over the long term. Impacts associated with reduced amounts of arable land and increased demands for arable land as well as reduced agricultural productivity could result in long-duration impacts, experienced locally.

With a decreased agricultural base as a result of the proposed Project, increased trespass on adjacent forest reserves to obtain forest products and to cultivate land for crop production could occur. Increased trespass into forest reserves would be a long-term impact that would further degrade the quality of the Ajenjua Bepo, Auro River, Maman River, and Kajeasi forest reserves.

CUMULATIVE EFFECTS

Cumulative effects on flora would result from the proposed Project and ongoing or reasonably foreseeable future activities in the region surrounding the Proposed Mining Area. Native vegetation in forest reserves would experience cumulative impacts from legal and illegal mining, development of agricultural land in forest reserves and illegal logging in forest reserves. Planting of non-native trees would reduce the diversity of the native flora. With increased human activities that disrupt soil and vegetation, there would be increased potential for invasive weeds to become dominant and displace less aggressive native species. Construction of electrical transmission lines would result in the loss of trees within and near the right-of-way.

ANNEX D-2

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; FAUNA

ANALYSIS OF IMPACTS TO FAUNA

DIRECT IMPACTS

Development of mine-related facilities would result in direct loss of wildlife habitat (secondary forest, fallow and crop land) until the land (except portions of the mine pit) is reclaimed following mining. Loss of habitat would reduce local availability of forage, security and breeding cover for wildlife inhabiting the area. All species dependent on disturbed sites would be killed or displaced. Displaced animals may be incorporated into adjacent populations, depending on variables such as species behaviour, density and habitat quality. Adjacent populations may experience increased mortality, decreased reproductive rates or other compensatory or additive responses as a result of movement of wildlife from disturbed areas to adjacent habitats.

Removal of habitat, displacement and direct mortality from mine-related disturbance would have the potential to affect species restricted to forest habitats (“obligate forest species”) and species that occupy forest and non-forest habitats (“habitat generalists”). Removal of approximately 175 hectares of forest habitat for the mine development would have the potential to affect a range of species adapted to forest habitats. Removal of an additional approximately 1,275 hectares of cropland, fallow and plantations would have the potential to affect species adapted to habitats affected by high levels of human activity. Species that would be affected by removal of forest habitat include Maxwell’s duiker, black duiker, royal duiker, bush buck, spot-nosed monkey, pangolins, fruit bats, birds, amphibians and reptiles. Removal of non-forest habitat, currently land used for agroforestry, would affect habitat generalists including bush baby, Bosman’s potto, cusimanse, dwarf mongoose, giant rat, grasscutter, ground squirrel, bats, small mammal, amphibians and reptiles. Larger, more mobile species would likely relocate from construction activities areas to adjacent habitats whereas smaller, less-mobile species and young of some species could be killed during the construction phase of the Project.

Development of the proposed Project would displace wildlife from approximately 1,275 hectares of agricultural/fallow habitat and approximately 175 hectares of forest habitat. Removal of agricultural/fallow habitat would have an undetectable effect on local and regional populations because these habitats are widespread and interconnected. Direct mortality to birds would result if mine construction were to destroy nests with eggs or young. Loss of eggs and young would have negligible effects regionally because species of birds typically associated with crop land and fallow fields are generally common and large areas of habitat unaffected by mining are available locally and regionally.

Removal of forest habitat could reduce capacity of the Ajenjua Bepo Forest Reserve to support current numbers and diversity of forest birds. Beier *et al.* (2002) studied birds in forests of central Ghana, including the Ajenjua Bepo Forest Reserve, and found that as the size of contiguous forest decreased, species richness of birds decreased. Losses of forest birds occurred in forest habitats of less than several hundred hectares. Currently, the Ajenjua Bepo Forest Reserve is 569 ha. With proposed mining disturbance, the Ajenjua Bepo Forest Reserve would be reduced to 495 hectares.

Losses of trees and associated forest habitat could reduce species diversity and numbers of obligate forest species in the Ajenjua Bepo Forest Reserve. This incremental loss would cumulatively reduce the capacity of forests in Ghana to support species dependent on forest habitats. Locally and regionally, forest habitats are being degraded by fire, timber harvest and other land use activities.

The following species, listed by IUCN as having special status because of rarity or risk of extinction, would have the potential to be affected by the proposed project: Maxwell's duiker (Near Threatened), black duiker (Near Threatened), royal antelope (Near Threatened), Zenker's fruit bat (Near Threatened), horseshoe bat (Near Threatened), Pel's flying squirrel (Near Threatened), green-tailed bristle-bill (Vulnerable), hinged tortoise (Vulnerable). Several species protected under the First Schedule, Ghana Wildlife Regulations have been recorded in the area of the mine foot print (e.g., black kite, hooded vulture, bush baby, and Bosman's potto). It is unlikely that adults of black kite and hooded vulture would experience direct mortality from development of the mine because they are mobile and would avoid human activities. The black kite and hooded vulture are common scavengers around villages and nest in trees, often near villages. If trees with active black kite and hooded vulture nests were destroyed, young and eggs would be lost; however these species are common and loss of a small number of nests would not affect local or regional population viability. Other species of conservation concern recorded in habitats of the Mamang River Forest Reserve (e.g., bay duiker, bongo, black-and-white colobus monkey, Mona monkey, rufous-winged illadlopis would not be directly affected by the proposed Project.

Development of the proposed Project would result in an unvegetated, disturbed area with increased levels of human activity and noise; consequently, wildlife movement and use of habitat within and around the mine site and ancillary facilities would be inhibited and habitat security would decline. The extent of wildlife movement among the adjacent forest reserves has not been evaluated; however, there is probably little migration or movement of obligate-forest mammals, amphibians and reptiles through the matrix of altered habitats outside of the forest reserves where most mine facilities would be located (excluding the mine pit).

Currently, the forest reserves are isolated habitats and may become more isolated by proposed mine development. Habitat isolation inhibits genetic exchange among regional populations, which can threaten population viability. Habitat generalists, occupying habitats both in and out of the forest reserves, likely move freely among the forest reserves and through habitats outside of the forest reserves. Bird species adapted to forest habitats move among adjacent forest reserves more freely than mammals, amphibians, and reptiles.

Localized disruption of wildlife movement patterns by mine operations would not affect regional migrations or seasonal movements of wildlife. Wildlife adapted to agricultural and fallow plant communities with interspersed human settlements (i.e, habitat generalists) would avoid mine activities; however, this avoidance would not have local and regional effects on genetic exchange and would not cause fragmentation of non-forest land surrounding the Project. Obligate forest species would not likely leave the security of existing patches of forest to cross the matrix of habitats altered by agricultural, residential and industrial developments.

The Project is located in an extensive matrix of crop land and plant communities in early stages of ecological succession. Wildlife movement and habitat use in this matrix (with the exception of bats) appears to be local and not directed by regional factors. Migration and reproduction of bats is largely determined by onset of the rainy season. Fruit bats may migrate hundreds of kilometres seasonally in response to food availability. The Project would have no effect on regional migration patterns of fruit bats.

Loss of habitat and displacement from areas of disturbance would cause long-term, local impacts. Direct mortality would not affect the viability of regional wildlife populations; however, mortality and loss of habitat would cumulatively contribute to local and regional adverse effects on wildlife and their habitats from numerous factors associated with intensification of land use, fires and resource extraction.

Although loss of a few nests with eggs and young would not jeopardize population viability of the species, mortality induced by mining appears to conflict with the protection of First Schedule species listed under the Wildlife Conservation Regulations. Loss of eggs and young could be avoided by constructing mine facilities during periods when birds are not nesting and rearing young.

The bush baby and Bosman's potto are nocturnal, tree-dwelling primates that may seek shelter in trees that would be removed by mine development activities; consequently, they may be vulnerable to mortality associated with clearing of vegetation for the Project.

Habitat loss and possible mortality of species with conservation priority (First Schedule, Ghana Wildlife Regulations), as a result of the proposed Project, would result in site-specific losses of species diversity. Population densities of species of conservation priority would be substantially reduced on areas altered by mine development; however, the proposed Project would not likely have detectable effects on regional population numbers or result in loss of population viability and associated decreases in biodiversity, consequently impacts from the proposed Project would be negligible.

INDIRECT IMPACTS

Indirect effects of developing the mine and ancillary facilities would result from increased population density and reductions in wildlife habitat. Human populations would increase in density and, consequently, greater demand would be placed on habitats undisturbed by mining activities to provide bushmeat and agricultural products. Currently, hunting for bushmeat is severely affecting populations of wildlife in Ghana (Ghana Ministry of Lands, Forestry, and Mines 2002). Three species that would be displaced from mining activities and experience habitat reductions (i.e., grasscutter, Maxwell's duiker and royal duiker) are preferred bushmeat species and would be subject to increased hunting pressure as a result of increased human population densities and decreased local habitat. Indirect effects from construction and operation of the mine would be long term and local. An incremental local increase in mortality for bushmeat species is likely.

The Mamang River Forest Reserve would not be directly affected by the proposed project; however, increased human population adjacent to the reserve would likely increase utilization of the forest for bush meat hunting and extraction of other natural resources.

Species of conservation concern that could be affected by increased bush meat hunting and other human activities include the bongo, black-and-white colobus monkey, Mona monkey, duiker species, round-leaf bat, Zenker's fruit bat and rufous-winged illadopsis.

CUMULATIVE EFFECTS

Cumulative effects to wildlife and wildlife habitat would result from legal and illegal mining, encroachment of farming into forest reserves, illegal logging and bushmeat hunting. On a regional basis, increased human activities that remove or degrade wildlife habitat and disrupt genetic interchange among isolated populations (usually in forest reserves) would cumulatively reduce diversity of habitats and wildlife species that are dependent on forest vegetation. With increased human activities regionally, wildlife adapted to altered habitats (habitat generalists) could increase.

ANNEX D-3

**DIRECT, INDIRECT AND CUMULATIVE
IMPACT ANALYSIS; WETLANDS**

ANALYSIS OF IMPACTS TO WETLANDS

DIRECT AND INDIRECT IMPACTS

The proposed Project would result in the filling of approximately 14 hectares of wetlands in ephemeral drainages as a result of construction of the Tailings Storage Facility, waste rock storage facility, Water Storage Facility and other mine-related facilities. None of the wetlands that could be affected have been identified as having high ecological functions and values, warranting national conservation priority. It is expected that new wetland vegetation would become established along the shoreline of the Water Storage Facility, which would be a long-term benefit because the Water Storage Facility would remain after mine closure as part of the proposed Project.

At cessation of mining, part of the mine pit would gradually fill with water and eventually form a lake. The quality of water that would form in the mine pit appears to be adequate to support aquatic vegetation and wetland vegetation could establish itself along the littoral zone of the pit lake.

CUMULATIVE EFFECTS

Cumulative effects to wetlands would include ongoing farming practices, unpaved roads, small-scale mining and other human activities that remove vegetation and expose soil to erosion. Erosion of sediment into surface water and wetlands could fill and degrade ecological functions and values provided by wetlands.

ANNEX D-4

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; AQUATIC RESOURCES

ANALYSIS OF IMPACTS TO AQUATIC RESOURCES

DIRECT AND INDIRECT IMPACTS

Construction of the Water Storage Facility, waste rock disposal facilities and Tailings Storage Facility on existing drainages would directly affect fish and aquatic invertebrates inhabiting the ephemeral or intermittent drainages present in these areas. In addition, to the extent these areas are used seasonally when water is available for spawning, rearing, and/or refuge habitat by fish from the main stem rivers in the Study Area, development of mine facilities will alter or eliminate those uses in the affected stream reaches.

Members of the African tetra family of fishes have been shown to move into the tributary streams from the main stem and likely use these areas for spawning and rearing habitat. They have been found to leave the tributary streams during the dry season, apparently returning to the main stem rivers (Geomatrix 2007c, Geomatrix 2008c). There are reports of reductions in these fish following the disruption of these seasonal migrations through the placement of dams in eastern Africa (Gratwicke et al. 2003). Members of this family of fishes are currently among the most common and widespread of the fish species encountered in the Study Area.

With construction of the Tailings Storage Facility and waste rock disposal facilities in these tributary drainages, the local aquatic habitat will be permanently eliminated. To the extent these facilities will isolate the upper-most portions of the drainages from having direct connections to the lower tributary reaches and/or main stem rivers, remnant fish populations will be isolated and prevented from seasonally migrating into and out of these areas. These direct effects will likely result in decreasing the diversity and abundance of fish that use these local areas and may eliminate fish populations in the upper most reaches of these tributary streams when flow does occur. Because these facilities would be constructed in drainages that represent a small percentage of the habitat in the Study Area, the overall impacts to aquatic resources from facility development are expected to be small.

In contrast, development of the Water Storage Facility, while blocking migration below the dam, will transform limited flowing water habitat into a lake environment. Many of the species found in the Study Area streams will be able to adapt to these changes and will likely thrive in this new habitat. The volume of this lake will likely greatly exceed the area of habitat lost through development of the tailings and waste rock disposal facilities. The net effect of facility development, therefore, may be an increase in fish and aquatic invertebrate production. This new habitat will, however, be of a different nature than the habitat lost and will be effectively isolated from the other streams and rivers in the vicinity of the mine. Establishment of the Water Storage Facility, however, would create a long-term environment for supporting fish and aquatic life. The mine pit area remaining after mining would eventually fill with water and would also likely support fish and other aquatic organisms.

Diversion of water from the Pra River to the Water Storage Facility would occur only during high flow periods. Consequently, the impact of this diversion would not be expected to directly affect fish and other aquatic organisms by reducing water volumes to stressful levels. Overall impacts to fish and aquatic organisms would be minimal with implementation of the proposed Project.

CUMULATIVE EFFECTS

Cumulative impacts to fish and other aquatic organisms would include ongoing farming practices, unpaved roads, and human activities that remove vegetation and expose soil to erosion. Erosion of sediment into surface water adversely affects fish and aquatic invertebrates by altering feeding efficiency, reproduction, and use of habitat. Any unchecked erosion and increased sedimentation resulting from the Project would add to this “base load” of sedimentation resulting from these other human-created sources.

ANNEX D-5

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; AIR RESOURCES

ANALYSIS OF IMPACTS TO AIR RESOURCES

DIRECT AND INDIRECT IMPACTS

Industrial emission sources in Ghana include aluminium smelter and alumina transportation, oil refineries, cement and asbestos plants, steel works, sawmills and wood processing plants, and gold, bauxite and manganese mines. Emissions from these sources include:

- Fluorides,
- Sulfur dioxide and other sulfur oxides,
- Nitrogen dioxide and other nitrogen oxides,
- Carbon monoxide,
- Condensed sulfate particles,
- Condensed nitrate particles,
- Alumina dust,
- Asbestos particles,
- Cement dust,
- Iron oxides,
- Antimony oxides and
- Dust.

While an entire year of ambient air quality measurements are not yet available for the Study Area, initial sampling results indicate that air quality in the Study Area meets organisation standards, with the exception of high wind and dust periods (such as during the “Harmattan” wind period). Under these circumstances, concentrations of particulate matter may exceed standards for short periods. Particulate matter in these cases is mainly composed of silicon dioxide minerals.

Ghana has established environmental quality standards for industrial/facility effluents and air quality under Section 28 of the Environmental Protection Agency Act, 1994, Act 490. Ambient air quality guidelines are set forth in Regulation 8 and on Schedule 3. These guidelines are summarized in **Table D5-I** for the primary compounds expected from the Project. In addition, according to the World Bank, the most frequently used reference guidelines for particulate matter are those of the World Health Organisation (WHO), European Union (EU), and standards of the USEPA. The WHO and USEPA guidelines/standards have been set based on clinical, toxicological and epidemiological evidence. Guideline values of ambient particulate concentrations were established by determining concentrations with the lowest-observed-adverse-effect. The EU guidelines have been determined by consultation and legislative decision-making processes that consider environmental conditions and economic and social development of the various regions.

Ghanaian guidelines, USEPA and EU standards, and WHO guidelines are listed in **Table D5-I**. Although this project is not located in the United States or Europe, USEPA and EU standards are presented for comparative purposes.

TABLE D5-I Air Quality Standards and Guidelines						
Source	Basis		Pollutant Concentration ($\mu\text{g}/\text{m}^3$)			
			SO ₂	NO _x	PM ₁₀	Particulates
Ghana	1-Hour	Average (Industrial)	900	400	---	---
		Average (Residential)	700	200	---	---
	24-Hour	Average (Industrial)	150	150	70	230
		Average (Residential)	100	60	---	150
	Annual	Average (Industrial)	80	---	---	75
		Average (Residential)	50	---	---	60
USEPA	24-Hour	Max	366	---	150	---
	Annual	Average	78	100	50	---
WHO	10-Minutes	Average	500	---	---	---
	1-Hour	Average	---	200	---	---
	8-Hour	Average	---	---	---	---
	24-Hour	Average	20	---	50 ¹	---
	Annual	Average	---	40	20	---
EU	1-Hour	Average	350	200	---	---
	24-Hour	Average	125	---	50 ²	---
	Annual	Average	---	40	40	---

USEPA = United States Environmental Protection Agency; WHO = World Health Organisation; EU = European Union; mg/l = milligrams per liter; $\mu\text{g}/\text{m}^3$ = micrograms per cubic metre; SO₂ = sulfur dioxide; NO_x = oxides of nitrogen; PM₁₀ = particulate matter 10 microns in diameter and smaller.

¹ Not to be exceeded more than 3 days per year.

² Not to be exceeded more than 35 days per year.

Operating statistics for the Project are shown in **Table D5-2** for the life-of-mine operation. A fugitive dust emissions inventory, shown in **Table D5-3**, indicates that fugitive dust sources from the proposed Project could exceed up to 600 tonnes annually, with the primary contributions resulting from wind erosion of exposed areas, mining of ore and waste rock, and placement of ore on the run-of-mine pad, and placement of waste rock in the waste rock disposal facilities.

Impacts to air quality resulting from emissions presented in **Table D5-3** can be estimated using air quality modeling techniques. Air quality models are commonly used to determine concentration increases caused by increases in emission rates. An air quality model is a mathematical representation of atmospheric behavior that allows concentrations to be calculated from meteorological data and information on quantities and locations of emissions being released.

For this Project, the Industrial Source Complex Short Term Version 3 (ISCST3) model was used. The ISCST3 model was developed by the USEPA and is the most commonly used air quality model in the United States. Emission rates used in the model are specified in **Table D5-3**. The emissions were placed in a series of area and volume sources used to represent

the mine pit, waste rock disposal facilities, hopper and roads, which are all considered to be sources of dust for the Project. A total of 199 separate emission sources were identified in the model.

Since long-term on-site meteorological data were not available for the Study Area, a screening approach was used where a series of one-hour meteorological scenarios are provided to the model, involving different combinations of wind speed, wind direction, and atmospheric mixing conditions. A total of 6,480 different one-hour meteorological scenarios were used in the model.

Year	Ore Rem Shov (Mt/Y)	Ore Haul (VKMT)	Ore Blast /Year	Waste Rem Shov (Mt/Y)	Waste Haul (VKMT)	Waste Blasts /Year	Water Truck Hours	Water Truck (VKMT)	Total Ore/Waste Haul (VKMT)
1	1.08	90,416	14	2.168	138,617	39	624	6,236	229,033
2	8.71	729,420	114	8.342	533,477	152	3,275	32,745	1,262,898
3	12.34	1,033,798	162	23.302	1,490,116	424	6,846	68,458	2,523,914
4	12.75	1,068,693	167	26.217	1,676,482	477	7,486	74,856	2,745,175
5	13.41	1,123,501	176	30.644	1,959,588	557	8,462	84,616	3,083,089
6	8.41	704,419	110	39.711	2,539,432	722	9,243	92,426	3,243,850
7	7.20	603,137	94	48.782	3,119,462	887	10,753	107,527	3,722,598
8	8.74	732,744	115	54.113	3,460,375	984	12,074	120,739	4,193,119
9	11.34	950,456	149	42.045	2,688,668	764	10,255	102,549	3,639,124
10	11.44	958,961	150	46.362	2,964,694	843	11,104	111,035	3,923,655
11	7.40	619,719	97	56.585	3,618,444	1,028	12,290	122,896	4,238,163
12	7.22	605,373	95	47.338	3,027,126	860	10,481	104,805	3,632,500
13	8.63	723,299	113	44.942	2,873,896	817	10,291	102,906	3,597,195
14	10.18	853,335	133	34.997	2,237,944	636	8,678	86,784	3,091,279
15	10.06	842,889	132	15.482	989,999	281	4,906	49,059	1,832,889
16	2.29	191,709	30	2.658	169,965	48	950	9,500	361,673

Notes: Mt/Y = million tonnes per year; VKMT = vehicle kilometres traveled.

Rem – Removal; Shov - shovel

Source: Lycopodium 2004.

Concentrations were computed at a series of 3,366 locations, called receptors, in the Study Area. These receptors were placed on a regularly spaced grid covering an area 13,000 by 10,000 metres, with the mining operation roughly at the centre of the grid. The spacing of receptors was set at 200 metres. One-hour concentrations were calculated at each of the 3,366 receptors for every one of the 6,480 meteorological scenarios and the results were sorted to determine the peak value at each receptor.

The final step in the process was to estimate longer averaging time concentrations for these peak values. The method provides simple factors for estimating 24-hour and annual average concentrations from one-hour concentrations. These values simply involve multiplying the one-hour value by 0.4 to obtain the 24-hour estimate and by 0.08 to obtain the annual average estimate.

**TABLE D5-3
Annual PM₁₀ Fugitive Emissions Summary for the Project**

Year	Fugitive Dust Emission from Mine-Related Activity or Disturbance Area (tonnes per year)										
	Ore Rem Shov	Ore Dump	Ore Haul	Ore Blast	Waste Rem Shov	Waste Haul	Waste Blast	Waste Dumping	Water Truck	Wind Erosion	Emission Total
1	0.3	1.0	6.0	0.1	4.9	9.2	0.2	4.7	0.2	85.0	111.6
2	2.7	8.3	48.3	0.4	18.8	35.4	0.8	17.9	1.0	85.0	218.7
3	3.9	11.8	68.5	0.6	52.4	98.8	2.2	50.1	2.0	85.0	375.3
4	4.0	12.2	70.8	0.6	59.0	111.1	2.4	56.4	2.2	85.0	403.8
5	4.2	12.8	74.5	0.6	68.9	129.9	2.8	65.9	2.5	85.0	447.2
6	2.6	8.0	46.7	0.4	89.4	168.3	3.7	85.4	2.7	85.0	492.3
7	2.3	6.9	40.0	0.3	109.8	206.7	4.5	105.0	3.2	85.0	563.6
8	2.8	8.4	48.6	0.4	121.8	229.3	5.0	116.4	3.6	85.0	621.2
9	3.6	10.8	63.0	0.5	94.6	178.2	3.9	90.5	3.0	85.0	533.1
10	3.6	10.9	63.6	0.5	104.3	196.5	4.3	99.8	3.3	85.0	571.8
11	2.3	7.1	41.1	0.3	127.3	239.8	5.2	121.7	3.6	85.0	633.6
12	2.3	6.9	40.1	0.3	106.5	200.6	4.4	101.9	3.1	85.0	551.1
13	2.7	8.3	47.9	0.4	101.1	190.5	4.2	96.7	3.0	85.0	539.8
14	3.2	9.7	56.6	0.5	78.7	148.3	3.2	75.3	2.6	85.0	463.2
15	3.2	9.6	55.9	0.5	34.8	65.6	1.4	33.3	1.4	85.0	290.8
16	0.7	2.2	12.7	0.1	6.0	11.3	0.2	5.7	0.3	85.0	124.2

Assumptions			
Value	Variables	Value	PM ₁₀ Emission Factors
100	wet days	0.002	Waste E_shov (kg/tonne)
0.3	PM10/TSP	0.0003	Ore E_shov (kg/tonne)
0.4	control suppressant	0.0010	Ore E_disposal facility (kg/tonne)
	water sprays on truck		
0.5	disposal facility	0.017	E_wind (kg/m2/yr)
8.6	silt (%)	0.066	Waste E_haul (kg/vkt)
15	speed ore (mph)	0.066	Ore E_haul (kg/vkt)
15	speed waste (mph)	0.029	Water E_haul (kg/vkt)
10	speed water (mph)	5.102	Waste E_blast (kg/blast)
2.5	tire correction factor	3.571	Ore E_blast (kg/blast)
		0.001	Waste disposal facility (kg/tonne)

Notes: PM₁₀ = particulate matter at 10-micron size; TSP = total suspended particulates; TPY = Tonnes per year; km/hr = kilometres per hour; kg = kilogram; hr = hour; yr = year; m³ = cubic metre; vkmt = vehicle kilometre traveled; Rem = removal; Shov = shovel.

Assumptions, aside from those listed above, include the following:

1. Projected Waste and Ore amounts are from Table 7.6.1, Lycopodium 2004.
2. Total Ore – 141,205,000 tonnes over 16 year period.
3. Total Waste –475,576,000 tonnes over 16 year period.
4. Ore and Waste Rear Haul Dump Trucks have an approximate payload of 90.7 tonnes and travel at 24 km/hr.
5. Ore and Waste number of blasts per year were provided by Newmont via email correspondence.
6. Open acres that would be susceptible to wind erosion were estimated from figures contained in Lycopodium 2004.
7. Pit area calculated from drawings contained in Lycopodium 2004.
8. The water truck will be in operation 24 hours a day for a total of 8,760 hours per year.
9. Haul road distances were estimated from drawing contained in Feasibility Study Update, Lycopodium 2004.

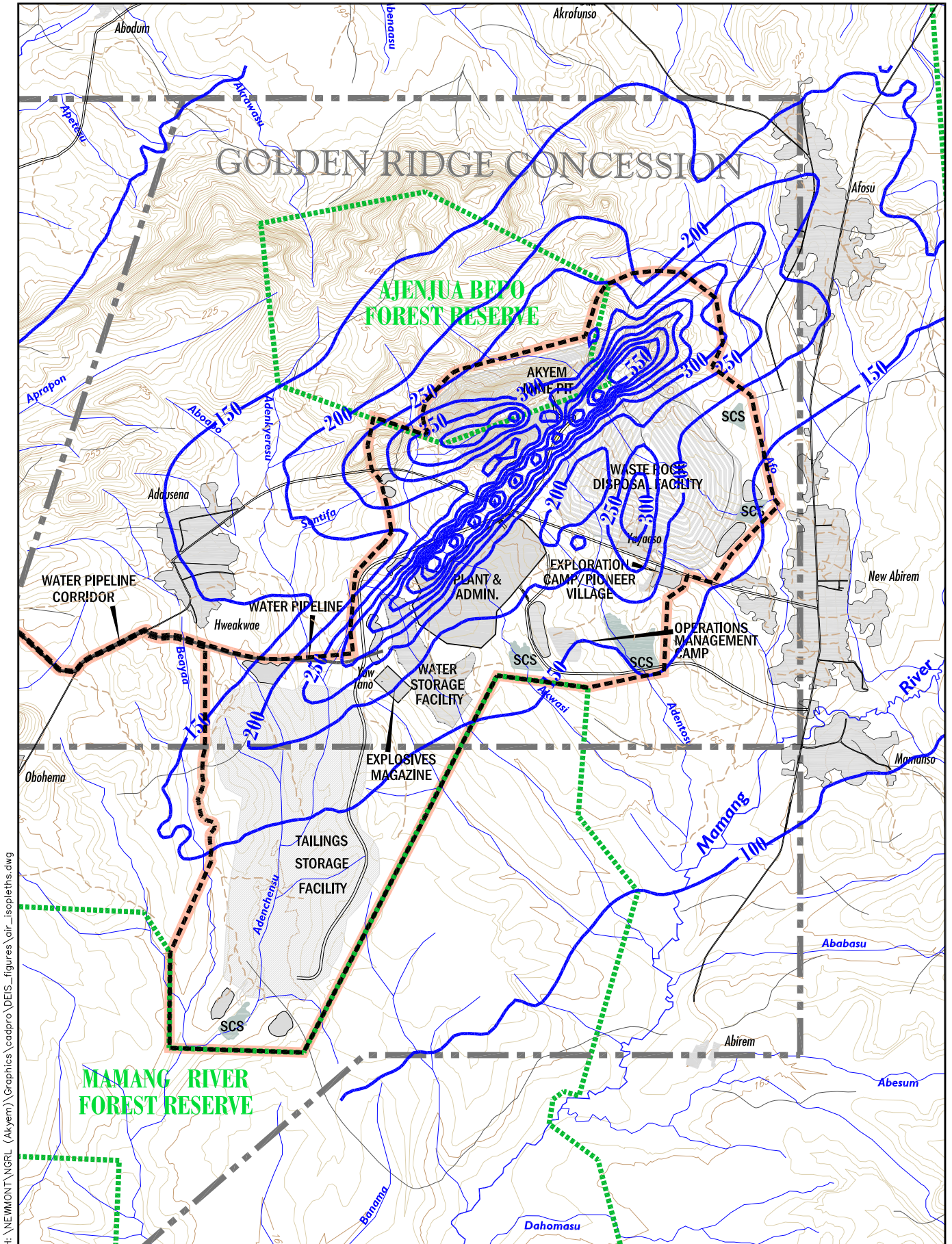
Results of the modeling analysis are depicted in **Figures D5-1** and **D5-2** showing isopleths of PM₁₀ concentrations (particulate matter 10-micron size) for the 24-hour and annual time averages, respectively. The figures may be compared to previously mentioned guidelines or standards.

For comparative purposes, using Ghanaian guidelines and USEPA ambient air quality standards, concentrations in excess of the ambient air quality standards for both 24-hour and annual averages are apparent for areas surrounding the mining operation. The annual average PM₁₀ concentrations predicted for Afosu, New Abirem and Adausena do not exceed the USEPA standard. For 24-hour values, PM₁₀ concentrations in excess of 250 µg/m³ are focused mainly on the haul road areas, although concentrations exceed the Ghanaian guidelines and USEPA standard beyond the primary mine facilities (i.e., mine pit, waste rock disposal facilities, and plant area).

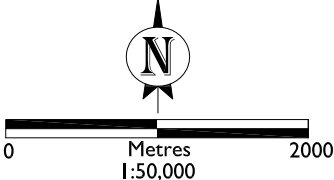
The primary cause of high dust concentration in the modelled area shown in **Figures D5-1** and **D5-2** is truck travel on un-sealed roads, dumping rock at the waste rock disposal facilities and handling ore at the primary crusher site near the processing plant.

CUMULATIVE EFFECTS

The nature of air quality impacts from mining operations is localized. As a result, even in areas where heavy mining activity occurs, air quality impacts of each individual mine typically do not overlap. The primary reason for this is that the principal air pollutant of concern for mining operations is fugitive dust. The relative size and density of fugitive dust particles are greater than the regional air quality particles. Large particle size and density leads to more rapid deposition of the suspended particles. As a result, most mining fugitive dust impacts are greatest in the immediate vicinity of each mining area and diminish rapidly with distance from the source (mine site). No cumulative impacts to air quality from the Project, therefore, are expected.

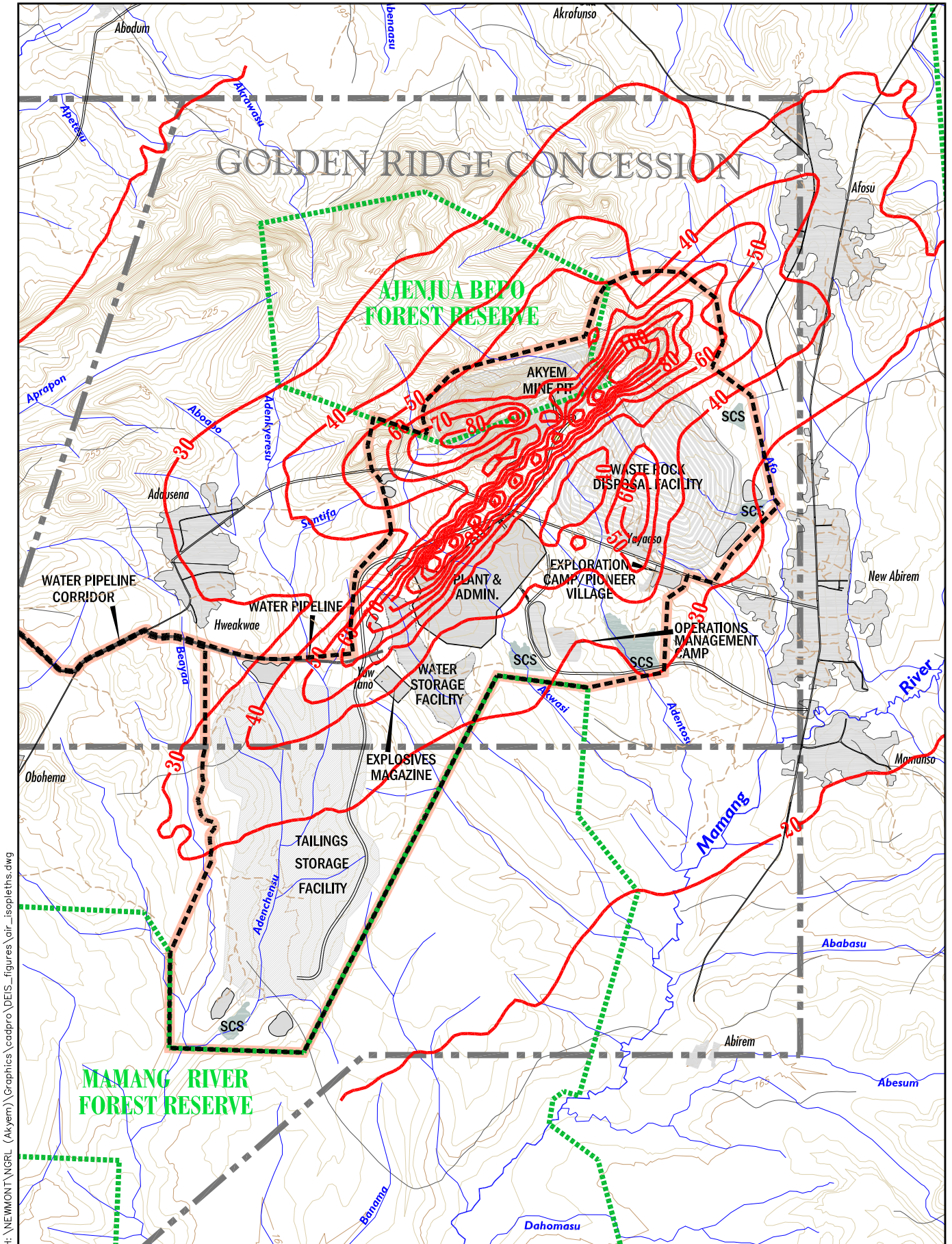


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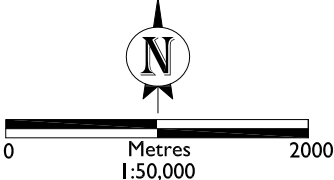


- Proposed Pipeline
- - - Concession Boundary
- - - Proposed Mining Area
- Forest Reserve Boundary
- Isopleths of 24-Hour PM-10 Concentrations ($\mu\text{g}/\text{m}^3$) Predicted From Mining Sources

Isopleths of 24-Hour PM₁₀ Concentration
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE D5-1



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- Proposed Pipeline
- - - Concession Boundary
- - - Proposed Mining Area
- Forest Reserve Boundary
- Isopleths of Annual Average PM-10 Concentrations ($\mu\text{g}/\text{m}^3$) Predicted From Mining Sources

Isopleths of Annual Average PM₁₀ Concentration
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE D5-2

ANNEX D-6

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; GEOLOGY AND MINERAL RESOURCES

ANALYSIS OF IMPACTS GEOLOGY AND MINERAL RESOURCES

DIRECT AND INDIRECT IMPACTS

Approximately 396 million tonnes of waste rock and 116 million tonnes of ore would be removed from mine pit in conjunction with the Project site during the 15-year mine life. Primary concerns associated with the Project are the quality of water that could seep through the waste rock disposal and tailings storage facilities, the quality of water that could run off the waste rock disposal facilities, the quality of water in the tailings storage facility during operations and the quality of water that would collect in the mine pit after cessation of operations. Construction of mine roads also exposes geologic materials to weathering, although most roads would be constructed in weathered saprolite which is expected to be relatively inert.

Sampling and characterization of geologic materials contained within the following mine facilities have been conducted by the Company based on general mining experience it has had at other sites (including the Ahafo Mine): mine pit; waste rock disposal facility; tailings storage facility; and new roads. These sites typically have potential for acid rock drainage and/or release of trace metals to the environment.

Geochemical Characterization Approach

The Company has conducted Phase 2 testing of single rock-type materials at the Project to confirm Phase 1 geochemical testing results and predict site-specific geochemical processes that may result from exposure of geologic materials to weathering. In response to this information, alternatives and/or mitigation measures can be designed to minimize or abate potential adverse effects of those processes. Exposure of rock in each of the mine-related facilities listed above to water and oxygen has the potential to change local rock-water interactions from those currently in process, thereby initiating geochemical reactions that may require additional mitigation steps beyond the environmental controls currently designed into the Project.

Prediction of potential metal release over the long-term can be difficult due to the complexity of weathering processes and the number of physical, chemical, biochemical, mineralogical and hydrogeological variables involved. The Company developed material sampling and analysis strategies that optimize data required to model and predict potential geochemical impacts, not only before mining begins, but during mining to identify potential changes in these variables as they are encountered.

Specific data used to identify site-specific geochemical processes include:

- Baseline water quality data (see *Water Resources* section).
- Mineralogical composition of samples from within the mine pit area for determining percentage of sulfide minerals, which can potentially generate acid, and carbonate minerals, which can potentially neutralize any acids generated.
- Whole rock analysis of selected metals in the same samples from the mine pit area.

- Chemical analysis of ore and waste-rock material using acid-base accounting static tests of oxide, sulfide, and single rock-type samples for acid neutralization potential (ANP), acid neutralization potential acidity (ANPA), acid generation potential (AGP), and net carbonate value (NCV), expressed as percent carbon dioxide (%CO₂).
- Further chemical analyses to characterize leachate from the samples by simulating weathering conditions using a variety of test methods, such as synthetic precipitation leaching procedure (SPLP), peroxide acid generation (PAG), and biological acid preparation potential (BAPP).
- Bulk leach tests to simulate the milling process of oxide and primary (sulfide) ore samples and results of cyanide detoxification tests; and mineralogy, whole-rock chemistry, tailings slurry water quality and acid-base accounting for tailings solids.

This information allows the Company to confirm existing data (acid-base accounting and potential release of trace metals) and identify the need for alternative material handling procedures and/or mitigation measures. Once data are available, models can be developed or revisited to predict changes to: (1) the quality of water that would result from exposure of geologic material to surface weathering processes during construction of the mine pit, waste rock disposal facilities and roads; (2) the quality of water that could seep from the waste rock disposal facilities and discharge from the tailings storage facility underdrain system; (3) the quality of water that may collect in the mine pit during and after operations; and (4) chemical constituents that would be present in tailings solids and water stored in the tailings storage facility.

Geochemical Characterization of Rock Samples

Phase 1 and Phase 2 samples of oxide and sulfide intervals were analyzed using static test procedures (acid-base accounting) as an initial assessment for potentially acid-generating rock at the Akyem Gold Mining Project. **Tables C3-2, C3-3 and C3-5** (Annex C3) contain values of acid neutralization potential (ANP), acid generation potential (AGP), and net carbonate values (NCV). NCV, the sum of ANP + AGP, provides an estimate of the net acid-base potential of the rock. Positive NCV indicates a net neutralizing potential, while negative NCV indicates a net acid-generating potential. The magnitude of the NCV provides an indication of the strength of the neutralizing or generating potential. Details on NCV classification are provided in Section 3.0 and Annex C3.

The U.S. Bureau of Land Management (1996) uses a term called “net neutralizing potential” (NNP) and ANP:AGP ratios to classify the acid-generating potential of rock. When comparing the US BLM classification to NCV classification, acid generating = highly acidic (HA) and acidic (A); uncertain = slightly acidic (SA), neutral (N), inert (I), and slightly basic (SB); and non-acid generating = basic (B) and highly basic (HB).

Phase 1 results show that average NCV's for the sulfide zone are classified as basic (1 to 5 percent CO₂), while the oxide zone averages range from inert to basic. The Phase 1 NCV classification shows little potential for acid generation. For Phase 2 testing, the Company prepared 16 composite samples that are representative of each waste rock type to be encountered during mining (4 major rock types and 12 minor rock types) for ABA analyses, mineralogy and whole-rock metals. NCV results from Phase 2 were compared to the Phase

I data to confirm the previously assigned NCV classification for each of the 16 rock types. In addition, specialized tests were performed to further assess the potential for acidity and metals release.

ABA results, including ANPA, for the 16 Phase 2 composite samples show the major waste-rock types that contain sulfide are basic (1 to 5 percent CO₂), indicating no potential for acid generation. The major oxide composite is classified as slightly basic (0.1 to 1 percent CO₂). One sample of the minor waste-rock types is classified as slightly acidic, one sample is inert, four samples are slightly basic; these six samples indicate an uncertain potential to generate acid, while the other six minor rock types are basic with no potential for acid generation. The volume of waste rock material present within the proposed mine pit that could produce acid is a small portion of the total rock volume that would be mined. The ANPA-based NCV data show that bulk of the ore and waste rock from the mine pit would have little potential to generate acid upon exposure to atmospheric conditions and would have capacity to neutralize acid production.

Whole-rock chemical data from the 207 Phase I samples and the 16 composite Phase II samples show enriched levels of some trace elements in comparison to the associated elements' average crustal abundance (antimony, arsenic, beryllium, molybdenum, lead, selenium, and thallium), so additional geochemical characterization was performed to evaluate the potential impacts on water quality. While whole-rock concentrations above those found in average crustal rocks does not guarantee that constituents will be released to the environment, it raises the possibility that they could be released in concentrations exceeding water quality standards. The specialized SPLP, BAPP, and PAG tests showed exceedances of Ghanaian Drinking Water Company standards in at least one of the tests for the following metals: aluminium (Al), antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), thallium (Tl), and zinc (Zn).

Analysis of potential impacts assumes that the waste rock will be placed in the mine pit as part of the closure and decommissioning plan. It is anticipated the pit remaining will fill with water to produce a pit lake. Potential impacts on surface water could result from infiltration of rain through the waste rock piles or leaching of pit walls or waste placed in the pit into the pit lake. Potential impacts on groundwater quality, although believed to be much less significant than impacts on surface water quality, could result from infiltration of rainwater through the waste rock piles to the water table or outflow through the placed waste material or fractured bedrock in the mine pit.

Preliminary geochemical modeling of pit lake water quality was conducted in 2006 assuming no pit waste placement and using limited existing data. Thus, the results may not best represent conditions under the current scenario (i.e., waste placed in pit). Chemical data for input to the modeling was obtained from three existing monitoring wells. Pit lake modeling results predict a near neutral pH (~6.6 to 6.7) remaining essentially constant over the 200-year timeframe that was modelled. The only metal predicted to exceed water quality criteria is thallium. However, analytical methods (i.e. detection limits) may not have been sensitive enough for some of the other trace metals of interest, such as arsenic or antimony.

Assessment of Tailings Characteristics

Two tailings samples (oxide and sulfide) generated from metallurgical bench-scale work were chemically analyzed to assess the potential for acid generation and trace-metal release (Knight Piesold 2002). Analyses included mineralogy, whole-rock chemistry, chemistry of the tailings slurry water, and acid-base accounting. The mineralogical results were similar to those presented earlier for the waste rock samples. Both pyrite and ankerite were present in trace amounts in the oxide sample and were classified as accessory in the sulfide sample. Both samples were found to have very low potential for acid generation. Both tailings solids were significantly enriched in antimony and molybdenum above crustal averages.

Results for the tailings slurry water show the following parameters to be above background reference concentrations for surface water in Canada and Australia: aluminium, arsenic, cadmium, chloride, cobalt, chromium, copper, iron, nickel, phosphorus, pH, phosphorus, potassium, selenium, silver, sulfate, uranium, and zinc, in the tailings slurry water; cyanide was also present at moderate to high levels. While molybdenum and antimony concentrations in tailings slurry water were below the surface water background standards, the concentrations are above the Ghana Water Company water quality standards. Predictions of impacts related to potential releases from the tailings facility are based upon testing of two tailings samples that predict no acid generation, but possible impacts on surface water quality related to trace metals (molybdenum and antimony) and on air, soil, and vegetation, if the tailings solids become dry and are exposed to wind.

Milling process-design solutions were submitted for cyanide detoxification testing as input to process design for efficient treatment of milling wastes. This treatment design process ensures that cyanide concentrations are below applicable water standards prior to discharge into the tailings storage facility. In the detoxification testing process, Caro's Acid (peroxide and sulfuric acid mix) is added to the tailings sample for varying lengths of time and in various stoichiometric proportions and allowed to react with any cyanide that might be present.

The Company, as a subsidiary of Newmont, is signatory to, and will comply with, the International Cyanide Management Code (ICMC). The ICMC recommends that concentrations of weak acid dissociable (WAD) cyanide at or below 50 milligrams per litre (mg/l) are generally considered low enough to be protective of most wildlife. Thus, concentrations of cyanide in the tailings facility supernatant pond would be managed through the CCD circuit to be maintained at or below the 50 mg/l target.

CUMULATIVE EFFECTS

Cumulative environmental geochemical impacts from development of the Project would be limited to potential increased loading of metals and other dissolved solids to water resources. No other existing or proposed mining projects have been identified in the vicinity (watershed) of the proposed Project. As such, no additive impacts associated with Project rock geochemistry and potential metal release from mine development have been identified.

Gold mining is a major activity in Ghana. Therefore, it is reasonable to assume that large-scale mining will continue, resulting in creation of open pits, waste rock disposal facilities, tailings storage facilities, water storage facilities, processing plants and associated ancillary facilities at other locations in Ghana. Small-scale and illegal mining in the Study Area also could occur and likely result in additional loading of metals and other chemical constituents to the environment.

ANNEX D-7

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; WATER RESOURCES

ANALYSIS OF IMPACTS TO WATER RESOURCES

SURFACE WATER QUANTITY AND USE

Construction of the proposed mine and ancillary facilities would directly affect about 1,428 hectares (**Table 2-1**) through removal of vegetation, soil and subsoil. Many of these facilities would be located across drainage bottoms such that natural seasonal flow would be blocked and/or diverted. The drainages are all tributary to, and on the north side of, the Mamang River, and are dry most of the year (i.e., ephemeral). The following summarizes primary mine-related facilities and their location relative to drainages:

- **Mine Pit:** This pit would be excavated over an area of 139 hectares, with the eastern part drained by small tributaries of the Afo stream, middle part drained by Adentosu stream, and the western part drained by the Akwasi stream, all of which flow south to the Mamang River. The proposed mine pit would be located near the upper reaches of these streams, with only the eastern drainage (tributary to Afo stream) extending from above to below the mine pit area. All of these tributary drainages flow only seasonally during major rain events.
- **Waste Rock Disposal Facilities:** The waste rock disposal facility would be constructed over an area of 246 hectares, south of the on the proposed mine pit. This area is drained by two tributaries to the Mamang River: Adentosu stream and tributary to Afo stream, both of which flow seasonally.
- **Tailings Storage Facility:** This facility would be constructed across the drainage bottom of the Adenkyeresu and Adenchensu streams, southwest of the proposed mine pit and plant site. The impoundment would cover an area of about 419 hectares at the end of mining and processing. The Adenkyeresu and Adenchensu streams flow only seasonally in response to major rain events.
- **Water Storage Facility:** This impoundment would collect water from the Pra River pumping station in the headwaters of a small tributary of the Mamang River, immediately southwest of the plant site. Surface water runoff diverted around some mine-related facilities also would be directed to the water storage facility. The impoundment would cover a maximum area of about 56 hectares when full. A spillway at the dam would direct excess water from the water storage facility into the downgradient tributary.
- **Sediment Control Structures:** Several earthen dam structures would be constructed in some of the small drainages that contain the mine pit, tailings storage facility, waste rock disposal facilities, and plant site to collect water that runs off disturbed areas and to allow sediment to settle behind the dams. These sediment control structures and associated diversion ditches would cover a total area of 35 hectares.
- **Process Plant, Mill, Administrative Offices, and Mine Services Site:** The Akwasi stream and another unnamed tributary of the Mamang River extend through the proposed plant site area. These ore processing facilities, however, would not be constructed in any channel bottoms. These drainages flow only seasonally in response to major rain events.

The plant site covers an area of about 85 hectares. A run-of-mine ore pad would be located between the plant site and waste rock disposal facility, covering an additional area of about 5 hectares.

- **Operations Management Camp:** The proposed camp for management staff would be located southeast of the waste rock disposal facility, covering an area of about 8 hectares. This camp would be situated between the Afo and Adentosu streams, which are tributary to the Mamang River.
- **Water Pipeline Corridor:** The makeup water pumping station would be located along the eastern bank of the Pra River approximately 8.5 kilometres west of the water storage facility. The water pipeline from the pumping station to the water storage facility would primarily follow drainage divides for tributaries of the Pra River to the west, and tributaries of the Mamang River to the east. The water pipeline corridor would cover a total area of about 17 hectares, assuming a corridor width of 20 metres.
- **Haul and Access Roads:** The various haul roads and access roads within the Proposed Mining Area would cover a total area of about 21 hectares. These roads would have adjacent diversion ditches to transport runoff water and sediment to the sediment control structures throughout the Study Area.
- **Other Facilities:** An additional 397 hectares of land would be affected by laydown yards, topsoil stockpiles, sand borrow areas, and power line corridors.

With the exception of the Water Storage Facility and sediment control structures, seasonal surface water that flows toward the mine facilities listed above would be diverted around them in channels designed to transport the 25-year, 24-hour storm event. Temporary diversion structures (<1 year life) would be designed for the 10-year, 24-hour storm event. Runoff from disturbed areas and water that collects in the mine pit during operations (direct precipitation and groundwater seepage) would be diverted to the larger sediment control structures and/or water storage facility. Settled water in the sediment control structures would then be released to the environment providing that it meets discharge standards. Excess water that collects in the tailings storage facility would be recycled to a process water pond at the plant site.

Outside of the direct disturbance areas described above, no disturbance would occur to drainages in the Proposed Mining Area. New roads associated with the mine project would require construction of culverts at stream channel crossings. These roads and stream crossings, however, would not affect surface water flow rates or quality in the drainages. Some short-term increases in sediment load to the drainages could occur during construction of the road crossings.

Changes in topography resulting from mining activities (mine pit and waste rock disposal facility), and construction of the Tailings Storage Facility, Water Storage Dam, plant site, and other associated project facilities would progressively modify watershed characteristics of the Mamang River tributary basins listed above. Overland runoff volume and peak flows could be higher as a result of vegetation removal for land development. Consequently, the surface water flow regime in the Proposed Mining Area would be changed. These changes, however,

would be minor because the Proposed Mining Area (1,903 hectares) represents approximately 0.4 percent of the total Mamang River drainage area of 475,000 hectares. In addition, the proposed mine facilities are located near the headwaters of tributary drainages.

A pump station is planned for the Pra River west of the proposed mine area to supply makeup water for ore processing. This will supplement water that collects in the water storage facility from surface water runoff. A water right would be obtained for the desired quantity from the river, which would be pumped primarily during the rainy season (i.e., May through October) to minimize adverse effects on fisheries and other beneficial users of the Pra River. Makeup water needed for the process plant facility from the water storage facility would be a maximum of about 0.1 cubic metres per second (m^3/sec) during the first 3 years, followed by about 0.04 m^3/sec for the remaining life-of-mine. The maximum rate of 0.1 m^3/sec is approximately 1 percent of average monthly flow (8.6 m^3/sec) for the Pra River at Prasokuma for the 6-month period of May through October; whereas the average makeup water rate of 0.04 m^3/sec is approximately 0.05 percent of average monthly flow for the Pra River. The pump station would be constructed along the river bank and would not require damming or changing the course of the river. The pump station and associated piping and access road would be removed after the pumping programme is completed and the area reclaimed and revegetated.

If the quality of water that collects in sediment control structures is acceptable, this water could be discharged back to the natural drainages, even though this water may be used for dust suppression. Mine pit sump water also would be discharged through the sediment control structures provided that it meets discharge criteria. Mine pit sump water that does not meet discharge criteria could be used as makeup water for the ore processing system further reducing pumping requirements on the Pra River.

Any surface water captured by mine-related facilities and not released back into the natural drainages would potentially be lost to downstream water users along the Mamang River. The tributary drainages that contain the proposed project facilities are ephemeral, containing water only during periods of heavy rainfall. Except for Yayaaso and the western portions of New Abirem and Mamanso, there are no villages or hamlets located directly downgradient from any proposed mine-related facilities for the Akyem Gold Mining Project. The Afo stream, located along the west side of New Abirem village, is located immediately downgradient of the proposed waste rock disposal facility.

Water that collects in the water storage and tailings storage facilities would be subject to evaporative loss that would be greater than natural evaporation from the watershed. Any flow in tributary channels upstream of these facilities would be diverted into the water storage facility. These drainages, however, flow only in response to major rain events. Direct precipitation falling onto the water storage facility and tailings storage facility would be collected in the impoundments. The waste rock disposal facilities can increase overland runoff due to steeper slopes and less vegetative cover; however, these effects would be localized.

Indirect effects on surface water quantity may occur from increased human population density and associated demands for crop production. With removal of land from production and resettlement of affected people to adjacent areas, population densities could increase locally.

Also, with construction and operation of the mine, more people will come to the area seeking jobs or would be employed at the mine. This could increase demand for surface water outside the Proposed Mining Area.

After cessation of mining and processing, the water storage facility may remain and continue to intercept water from some tributaries of the Mamang River. If the water storage facility remains after mining, water that collects in this impoundment would be available for users within the surrounding the basin. Water loss due to evaporation and seepage from the water body would continue. The tailings storage facility, waste rock disposal facilities, and plant site would be reclaimed with soil and vegetation, and therefore, would approach pre-mine runoff conditions. Most precipitation that falls onto these facilities would run-off or evapotranspire from the reclaimed surfaces.

A portion of the mine pit would remain open after cessation of mining. This open pit would mostly fill with groundwater and direct precipitation, with no discharge expected from the pit lake after cessation of mining (Golder 2006). Long-term evaporation would occur from the pit lake surface. The existing upgradient catchment area of approximately 150 hectares will be directed around the pit during operations. After cessation of mining, this runoff water would be allowed to flow into the mine pit if beneficial to post-closure land use.

SURFACE WATER QUALITY

Potential impacts to surface water quality from mine-related facilities can result from direct disturbance to the land (increased erosion and sedimentation), exposure of fresh rock and mineral surfaces to weathering and leaching (potential for acid generation and/or increased leaching of metals), and accidental spills of chemicals and petroleum products used for mine processing activities.

During mining and processing operations, no discharge of process effluent or other impacted water is planned from the tailings storage facility, mine pit, waste rock disposal facilities, and plant site. Water may be periodically discharged from the water storage facility, mine dewatering system, and/or sediment control structures if quality meets applicable standards and is approved by the EPA.

During implementation of the project, particularly the construction phase, land disturbance in tributary drainages to the Mamang River would result in increased erosion and sedimentation. The proposed mine facilities would be from 1.5 to 2 kilometres from the Mamang River. Without proper sediment control measures (i.e., sediment control structures in drainages), sediment from disturbed areas could reach the Mamang River. The closest mine facility to the Pra River would be the tailings storage facility at 6 to 10 kilometres from the river; however, no water from mining activities would directly discharge into the Pra River drainage basin.

Several sediment control structures would be constructed downgradient from the waste rock disposal facilities, mine pit, tailings storage facility, and plant site areas to collect and settle sediment in runoff water from these areas. As a result of these sediment control structures, no increase over background turbidity is expected in the affected drainages. A short-term increase in erosion and sedimentation may result during construction of the water pumping

station within the Pra River channel, and the water pipeline that would extend for approximately 8.5 kilometres from the river across several tributary channels that flow seasonally to the Pra and Mamang rivers.

Implementation of other Best Management Practices would help prevent increased sediment load to streams outside of direct disturbance areas. Such Best Management Practices would include: clearing land only when necessary and during the dry season; revegetating disturbed areas promptly; placing silt fences and straw bales down-slope of disturbed areas; constructing ditches and settling traps/ponds in close proximity to disturbed areas; and protecting native vegetation along drainage channels. Roads would be constructed with ditches to collect and convey water runoff from road surfaces to sediment traps or ponds.

An increase in suspended solids can render surface water less suitable for human consumption. As described in the *Surface Water Quality* portion of **Section 3.0**, baseline levels of suspended sediment or turbidity often are high. The presence of clay and silt throughout much of the Study Area results in elevated levels of suspended sediment in surface water. With the exception of most of the Pra River and lower Mamang River, the ephemeral or seasonal flow conditions of most tributary streams results in villages having more than one source of water (typically boreholes). Those with a single stream water source still manage to obtain water through dugouts excavated into the streambed during the dry season.

To evaluate potential for acid rock generation from the waste rock disposal facilities and tailings storage facility, numerous oxide and sulfide composite samples in the mine pit area were tested using static acid-base accounting methods (see **Section 3, Geology and Minerals**). Acid-base accounting analyses of Phase I (207 individual) and Phase II (16 composite) rock samples, obtained from multiple intervals in several boreholes within the Akyem deposit, as well as two composite tailings samples, indicate that sufficient neutralization capacity exists to prevent acid generation in the waste rock facilities, tailings storage facility, and mine pit area (pit lake). Geochemical testing also indicates that there is a potential for some trace metals to be released by water from the rock in low concentrations. Elevated concentrations of some constituents (e.g., antimony, arsenic, beryllium, lead, molybdenum, selenium, and thallium) could be present in the mine pit lake and water that infiltrates through the waste rock disposal facilities and tailings storage facility.

Although current evidence indicates that sufficient neutralization capacity exists to prevent acid generation and it is unlikely that trace elements will be released in significant quantities, the Company is conducting further rock characterization tests as part of the environmental monitoring programme to confirm preliminary results (see Section 6, *Monitoring*). In addition, the Company is completing more detailed geochemical characterization of geologic materials, including kinetic testing and meteoric water mobility testing, to expand on the knowledge base that has been developed.

Analysis of pregnant solution after leaching ore shows elevated concentrations of aluminum, barium, chromium, copper, iron, lead, manganese, molybdenum, nickel, strontium, zinc, and cyanide. This pregnant solution and tailings slurry, however, would remain in the process circuit and tailings storage facility and would not leave these facilities. The *Geology and Minerals*

discussion in **Section 3** discusses cyanide detoxification study results and information from other Ghana mining operations that indicate cyanide concentrations in supernatant ponds at tailings storage facilities are below 10 milligrams per litre (mg/l).

Sediment control structures located downgradient of the waste rock disposal facilities would collect any toe seepage water. The tailings storage facility would incorporate cutoff walls and underdrain systems to collect and prevent seepage to groundwater and/or control migration of tailings water offsite. During operations, this water would go to a lined collection basin and then be pumped to the plant site for makeup water. After operations, water discharging from these facilities would be recirculated and/or treated until acceptable quality is achieved.

Typical reagents to be used for mine processing include sodium cyanide, lime, caustic, hydrochloric acid, activated carbon, and flocculant. These materials would be transported and stored according to the International Cyanide Management Code in a secure area within the plant site. A fuel storage area also would be located in the plant site with approved containment for gasoline and diesel fuel. Accidental spillages of oil could occur from drums stored in inappropriate conditions or from vehicles that have mechanical problems.

Discharge of water containing cyanide or other chemicals would be prevented by operating all gold extraction and processing operations using a water/chemical solution recycle system. Secondary containment has been designed for all process piping, tanks, and conveyor systems transporting chemically-treated ore to prevent releases to the environment during upset conditions. From the treatment plant, process residues would be pumped to the tailings storage facility where solids would settle. Supernatant water containing cyanide would be collected by floating pumps and piped to the process water pond at the plant site. All piping used to transfer tailings to the tailings storage facility and the decant return line would be contained in a lined trench. Therefore, no effluent would be released to the environment.

A package sewage treatment plant located near the plant site to treat sewage from the plant, mine services area, site administration, on-site accommodations, and Operations Management Camp. Treated effluent would be discharged to local drainages. This effluent would be monitored daily to ensure compliance with relevant discharge standards. Parameters would include pH, conductivity, turbidity, total suspended solids, chemical oxygen demand, biological oxygen demand, total and fecal coliforms, free chlorine, nitrates, and phosphates.

Only inert, dry solid wastes generated by the mine operations would be buried in a landfill constructed in one of the waste rock disposal facilities. This landfill would be constructed to minimise both the rate of infiltration and quantity of runoff available for infiltration. This landfill would be operated to have no adverse impact on surface water quality.

After cessation of mining and processing, the water storage facility may remain and continue to intercept water from some tributaries of the Mamang River. Water from this reservoir would only be discharged via the spillway during extreme precipitation events; however, the quality should have no adverse impact to the receiving water (tributary of Mamang River). The tailings storage facility, waste rock disposal facilities, and plant site would be reclaimed with soil and vegetation, and therefore, would approach pre-mine runoff conditions. This runoff may have increased levels of sediment during the first few years of reclamation until vegetation

becomes well established. A portion of the mine pit would remain open. Natural surface water runoff from a small upgradient catchment area would be allowed to enter the pit after cessation of mining.

GROUNDWATER QUANTITY AND USE

Groundwater quantity in the Proposed Mining Area could be affected by removal of groundwater via pumping wells for potable water and for intercepting groundwater during development of the mine pit. The water storage facility would likely recharge groundwater in the vicinity of the impoundment. Groundwater resources are an important source of water supply for domestic and drinking purposes. In the various villages and settlements surrounding the Study Area (e.g., Afosu, New Abirem, Mamanso, Ahausena, and Hweakwae), boreholes are generally located within 2 kilometres from proposed mine facilities.

Several water supply wells are planned for completion within a radius of 5 kilometres from the mine area to provide potable water to the project. Each potable supply well would pump up to 12 cubic metres per hour (m^3/hr) periodically to maintain sufficient water in holding tanks. Pumping groundwater intermittently at these relatively low rates should not have adverse effects on groundwater levels or quantity in the Study Area.

The mine pit would be dewatered with sumps constructed inside the pit and/or with dewatering wells constructed around the perimeter of the mine pit. This water would be pumped to the surface for use as makeup water in the mill process circuit. Permeability tests conducted to date in bedrock in the proposed mine pit area show relatively low hydraulic conductivity values (Golder Associates 2004b, 2006). Additional well completion and testing will be conducted by the Company to further define hydraulic characteristics of mine pit area rocks and aquifers.

Golder Associates (2004b) used results of the various permeability tests described above to estimate groundwater inflow rates to the proposed mine pit. Average mine pit depth would be 315 metres. Depth to groundwater across the mine pit area before mining was assumed to be 10 metres below ground surface. Groundwater recharge over the mine pit area was assumed to range from 50 to 150 millimetres per year. Using these assumptions, Golder Associates (2004b) calculated a conservative steady-state groundwater inflow rate of 310 to 840 m^3/hr , although they indicate a more realistic range probably is 70 to 210 m^3/hr . Using another analytical approach, dewatering rates required to lower the groundwater level by about 400 metres over a period of 17 years averages 40 to 340 m^3/hr , using transmissivity values of 2 square metres per day (m^2/day) and 22 m^2/day , respectively.

As a result of mine dewatering, a groundwater cone-of-depression would develop around the mine pit area, expanding during the mining period, and recovering after cessation of mining. The magnitude and extent of this groundwater drawdown area will be estimated after the Company completes and tests additional bedrock wells in the mine pit in 2008. This radius of influence for groundwater drawdown could include nearby villages (e.g., Afosu, New Abirem, Hweakwae, and Ahausena). Any impacts to nearby village wells would likely occur for several decades as the groundwater drawdown area expands during mining and then recovers after mining.

Groundwater flow intercepted by mine pit development could reduce flow in nearby streams where groundwater is interconnected with surface water. These impacts, if any, are expected to be minor and localized because most surface water in the Study Area, with the exception of the Pra River and lower Mamang River, occurs primarily in response to major rain events.

After cessation of mining and dewatering, a pit lake would develop in the mine pit, with the water level eventually approaching pre-mine groundwater elevations, which is about 10 metres below ground surface over much of the proposed mine pit area. This would result in a pit lake depth of approximately 300 metres or more. Timing for pit lake filling is unknown, but is expected to be slow (i.e., decades) due to the relatively low permeability of most bedrock rock surrounding the mine pit. Slow filling of the pit lake could result in slow recovery of the groundwater drawdown area surrounding the mine pit. Evaporation from the lake surface would result in a loss of some groundwater that would otherwise not be lost to the atmosphere. Direct precipitation on the pit lake, however, would offset some evaporative loss. Another pit lake study to be initiated by the Company after completing and testing additional wells in the mine pit area, will evaluate whether water loss from evaporation would create a permanent “sink” where groundwater would always flow toward the mine pit lake.

Some water impounded in the water storage facility would seep into the subsurface and recharge local groundwater in that area. Seepage from the tailings storage facility is expected to be minor because of the seepage interception/collection system that would be constructed at the base of the facility. After cessation of mining and processing, groundwater pumping would cease for potable needs at the mine site (except for a small amount to support reclamation activities).

GROUNDWATER QUALITY

Quality of groundwater in the Study Area could be adversely affected by the waste rock disposal facilities, tailings storage facility, ore stockpiles, process water pond, mine pit, septic systems, and landfill. Each of these mine-related facilities is discussed below with respect to potential impacts on groundwater quality.

Tailings pond water would have elevated concentrations of some metals and cyanide. The tailings storage facility design incorporates a seepage interception/collection system and cutoff walls to prevent impacts to natural groundwater quality. A cutoff wall would be excavated through alluvium and highly weathered rock at the dam site; a seepage collection drain is proposed upstream of the cutoff wall where collected water would be pumped to a lined pond and then pumped back into the tailings storage facility or recycled to the process plant.

To prevent groundwater quality impacts in the process facility area, the process water pond would have multiple liners and a leachate collection system. Ore stockpiles would be constructed on low permeability clay material.

Tests of rock to be placed in the waste rock disposal facilities show low potential for acid generation potential, along with a high neutralization potential (see *Geology and Minerals, Section 3*). There is potential, however, that water infiltrating through waste rock would have elevated concentrations of some metals (e.g., antimony, arsenic, beryllium, lead,

molybdenum, selenium, and thallium), which could migrate down to groundwater and/or emanate as seeps from the toe of waste rock disposal facilities. Uppermost groundwater in this area generally flows south toward the Mamang River.

The waste rock disposal facilities would be constructed on low permeability clay soil similar to the ore stockpile areas. This prepared base of the disposal facilities would limit migration of potential contaminants from reaching groundwater beneath the facility. French drains would also be constructed in natural drainages within the footprint of the waste rock disposal facilities. Water would flow from the underdrain system to sediment control ponds at the toe of the rock piles where the water could be monitored for quality.

During mining, dewatering would create a groundwater cone-of-depression surrounding the mine pit that would keep groundwater flowing toward the open pit. Therefore, no impacts would occur to groundwater quality in this area. After cessation of mining, however, dewatering would cease and the mine pit would fill and approach a steady-state pre-mine groundwater level after several decades. At that time, water in the pit lake could mix with the natural groundwater flow system surrounding the pit.

Another pit lake study to be initiated by the Company after completing and testing additional wells in the mine pit area, will provide information regarding the relationship between the formation of an open body of water and the groundwater flow system in the mine pit area. Quality of water that would develop in the pit lake is being evaluated relative to ongoing geochemical studies described in the *Geology and Minerals* portion of **Section 3**. Kinetic testing of rock will provide information to confirm results of current whole rock and acid-base accounting tests. Some metals from pit wall rock could dissolve in pit lake water and potentially migrate in groundwater away from the mine pit.

If any chemicals used for mine processing (i.e., sodium cyanide, lime, caustic, hydrochloric acid, activated carbon, and flocculant) are accidentally released in sufficient quantities to the environment, they could infiltrate and impact shallow groundwater. Treated sewage effluent from the package treatment plant would meet applicable discharge standards prior to release into surface drainages and would not affect groundwater quality. As stated in **Section 3** (*Water Resources*), groundwater in some parts of the Study Area shows impacts by total and fecal coliform bacteria. Inert, dry solid wastes generated by the mine project would be buried in a landfill constructed in one of the waste rock disposal facilities to minimize both the rate of infiltration and quantity of runoff available for infiltration.

Any seepage of water beneath the water storage facility could have an indirect benefit of improving the quality of groundwater that could be impacted by the waste rock disposal facility and/or mine pit. All facilities associated with the plant site, such as the ore stockpiles and process water pond, would be removed and the site would be revegetated.

The tailings storage facility and waste rock disposal facilities would be reclaimed with soil and vegetation. This would minimize infiltration of precipitation into these facilities; however, some infiltration would continue. Any water that continues to discharge from these facilities resulting from infiltration of precipitation would be collected in the underdrain systems and toe ponds. This water would be recirculated and/or treated until acceptable quality is achieved.

CUMULATIVE EFFECTS

Cumulative effects to water resources from development of the Project would include potential increased loading of metals and other dissolved solids and suspended sediment to water resources. No other major land disturbing activity has been identified as occurring or proposed to occur in the drainage basins that would be affected by the Project. Contribution of trace metal release and/or suspended sediment to water resources resulting from the Project would be additive to other sources in the watershed including farming and agricultural practices.

Because gold mining is a major activity in Ghana, it is reasonable to assume that mining will continue, resulting in creation of open pits, waste rock disposal facilities, tailings storage facilities, water storage facilities, processing plants, and other associated disturbances. Locations of these future mines with respect to this Project, however, are currently unknown. All mine-related construction and operation would disturb the land and have potential for increased erosion and sedimentation to surface water drainages in those watersheds where mine development is occurring. Development of the Project is not predicted to create an additive impact to water resources when evaluated with other mine development within Ghana because of expected localized effects described above.

ANNEX D-8

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; SOIL RESOURCES

ANALYSIS OF IMPACTS TO SOIL RESOURCES

The Project would result in impacts to soil resources as a consequence of proposed surface-disturbance throughout the Proposed Mining Area as well as resettlement areas. Soil salvage efforts would remove topsoil prior to mining. Potential direct impacts to the physical, chemical, and biological properties of the soil resource in the Proposed Mining Area include reduced fertility, loss of soil structure, reduced infiltration, reduced water holding capacity, increased erosion, and reduced productivity relative to pre-mine conditions. Most of these impacts would occur as a result of soil handling and stockpiling activities. In addition, potential indirect impacts include effects on soil properties as a result of increased agricultural activity in the area immediately surrounding the Proposed Mining Area.

The degree and duration of soil impacts are largely dependant on soil handling methods employed during salvage, stockpiling and redistribution activities and the management practices employed during implementation of reclamation. Expected impacts are based on experience with soil handling operations and impacts to soil resources, an understanding of tropical soil, review of the soil resources in the Study Area as determined by survey (Geomatrix and SRI 2008) and consideration of the proposed activities associated with the Project.

Soil Salvage Depths and Volumes

Soil types in the Proposed Mining Area are characterized as having surficial materials (topsoil) that are better suited to plant growth than subsurface materials (subsoil). Relative to subsoil, the surface soil horizons have higher nutrient content, higher pH (less acidic), higher organic carbon content, and exhibit better tilth. In addition to being less suitable with regards to these properties, subsoil horizons of several soil series contain plinthite that could harden irreversibly upon drying and impede root growth. Selectively salvaging topsoil and suitable subsoil horizons and stockpiling them prior to commencement of other mining related operations would preserve many of the characteristics that make this material a suitable growth medium.

The approximate volume of soil available for salvage within the Proposed Mining Area was calculated using the average depths (centimetres) and extent of distribution (hectares) presented in Section 3.0. The evaluation of the soil survey data reveals that an average of 74 centimetres of material, including 15 centimetres of topsoil and 59 centimetres of suitable subsoil, are available for salvage within the Proposed Mining Area. Sufficient quantities of suitable plant growth materials in the Proposed Mining Area would be adequate to satisfy the closure and decommissioning reclamation requirements. Portions of the mine pit, access roads, and facilities not decommissioned would not require soil replacement, further adding to the excess of soil volume available for use in reclamation elsewhere.

While salvage depths would be series and site specific, it is not anticipated that soil from the various series would be segregated and stockpiled separately. Segregation by series would only be undertaken if necessary to preserve soil properties for selective placement in the reclaimed landscape. Topsoil and subsoil would be separately salvaged and stockpiled to the

extent practicable to ensure the properties of each are maintained. Soil volumes in excess of those required to achieve post-closure reclamation quantities could be salvaged to allow for additional replacement depth in areas requiring greater cover.

Effects of Soil Handling

Soil salvage and redistribution affects soil structure. As soil is handled, peds (natural soil aggregates) are crushed and larger natural pore spaces are eliminated. After soil is redistributed, large temporary pore spaces are created. These pores do not exhibit the same interconnectivity as that found in undisturbed soil and the structure providing them is less stable. Many of the pores that occur in the short-term following redistribution would shrink as soil settles over time.

Soil compaction from compaction often occurs coincident with destruction of soil structure. Some compaction of soil would occur during grubbing and clearing activities prior to salvage and again during redistribution of topsoil. Compaction leads to an increase in bulk density, root inhibition and reduced infiltration. These impacts could lead to reduced plant productivity, increased runoff, and erosion. Further compounding this effect is the presence of low-activity clay in the soil, which is common in the Proposed Mining Area. This soil has slight capacity to shrink and swell that would otherwise act to resist and reverse compaction. Effects of compaction are further increased through reduction in organic matter content and drying at high temperatures.

Active microbes would continue to oxidize organic carbon and release nutrients into the soil even after salvage. Oxidation, combined with partial blending of topsoil with subsoil that could occur during salvage operations, would reduce the organic matter content of salvaged topsoil relative to pre-mine conditions. As the soil is replaced on the regraded surface for reclamation, the soil would again be aerated and subjected to increases in temperature that would increase the rate of biological activity and further reduce organic matter content. Establishment of plants to immobilize nutrients released during these processes would limit leaching of nutrients from the soil.

A reduction in organic matter and nutrients resulting from soil handling operations would influence other soil properties. When organic matter is depleted, soil structure weakens and crusting following rainfall or saturation could become more common. Crusts forming on the soil surface inhibit shoot sprouting and decrease infiltration rates. Decreased infiltration rates and weaker structure could also result in increased runoff and erosion. A decline in topsoil organic matter would also lead to a reduction in cation exchange capacity (the ability of the soil to retain nutrients) and exchangeable bases (nutrients) and eventually to further acidification.

Immediately following replacement, soil not protected from intense rainfall events would be subject to water erosion. Erosion potential is further exacerbated by previously described impacts to soil structure and other characteristics reducing infiltration rates. Soil replaced on steep slopes (e.g., embankments and the waste rock disposal facility) would be especially

vulnerable to water erosion. Continued operation of sediment control structures and run-off collection ditches would result in capture of soil that moves from the site during the closure and decommissioning period. Soil capture in sediment collection facilities would be returned to reclamation areas.

Potential Effects of Non-Segregated Soil Salvage

Topsoil characteristics have an effect on the plant species that may be grown and the capability for agricultural production. In the pre-mine condition, suitability for agricultural production varies between soil series. In a similar manner, topsoil and subsoil of the series exhibits variable suitability for use in reclamation. As proposed, soil salvage operations would not segregate soil by series.

Effects of non-segregated salvage and resultant blending of soil would be most notable for topsoil due to the dependence on this surficial material for agricultural production. Blending moderately suitable soil with less nutrient-rich soil, combined with nutrient loss through handling, would affect the overall nutrient content of soil in reclamation. Blending soil with low coarse fragment content with high coarse fragment soil could result in a greater distribution of coarse fragments in the reclaimed area, potentially affecting suitability of the soil for certain uses. As indicated in **Section 8.0 (Closure and Decommissioning)**, the Company would evaluate topsoil replacement to arrive at a design that accounts for soil replacement that may vary according to location and soil type. The *Land Rehabilitation Plan (Annex G)* would also be refined within six months of commencement of operations and periodically updated to ensure the Company's revegetation programme goal of establishing a productive vegetative cover based on applicable land use plans and designated post-mining land uses is met.

Potential Effects of Planned Salvage and Replacement Depths

Post-mine landscapes and pre-mine soil depth conditions would likely vary resulting in slight alteration of topsoil and subsoil function. To maximise reclamation effectiveness, the rehabilitation plan would address several key areas to meet the Company's revegetation programme goals.

- Replaced waste rock in mine pits and waste rock disposal facilities: Topsoil redistributed over coarse waste rock or fractured bedrock would result in coarse fragment-dominated material nearer the surface than occurred in the pre-mine condition. Where erosion or anthropogenic influences result in removal of replaced soil, this rock could become exposed and render the soil unsuitable for cultivation. If the high coarse fragment material occurs within the rooting-zone, roots may be inhibited and plant available water may be reduced.
- Spoil materials: In areas where soil is redistributed over spoil material such as oxidized materials (e.g., saprolite) textures, rooting depths and stratification may be similar to pre-mine conditions. Comparison of pre-mine with post-mine conditions would be dependent on specific chemical and physical makeup of spoil material with rooting depth, permeability, and nutrient availability likely being the most affected properties. Where spoil material has high clay content or lateritic (including plinthite) materials,

permeability may be reduced and rooting depth may be limited at the soil/spoil interface if compaction occurs during spoil grading. Soil replacement resulting in covering this material before it is allowed to dry and harden would preserve the permeability characteristics of the material.

- **Tailings Storage Facility:** The suitability of the Tailings Storage Facility to support agricultural uses or other plant growth would be dependant on the thickness of the material replaced and the texture, drainage, and chemical properties of the underlying material. If textures are sandy, these materials may allow for greater root penetration, but may be less able to hold nutrients than the pre-mine subsoil. Tailings are often saturated materials that require some drying prior to soil replacement. Such wet conditions would be comparable to the conditions in natural valley bottoms, but may occur across a larger area. Tests of tailings that would be located in the root zone would indicate whether conditions are suitable for agricultural uses and what soil amendments would be needed to address identified conditions.

Increased Agriculture Activities Outside the Proposed Mining Area

Farming operations and other agricultural activities would be relocated to nearby areas in advance of mining operations. Relocated and new agricultural operations could impact soil in areas adjacent to the Proposed Mining Area as previously uncultivated areas and fallow are cultivated and planted, use of existing cultivated areas intensifies and fallow cycles shorten. The expected impact could be similar to the current effects of agriculture on soil in the area, which include reduced nutrient and organic matter content, destruction of soil structure, increased erosion, petroplinthite formation, and acidification among others. If agricultural uses are intensified, these affects may become more severe or occur more rapidly and as a result agricultural production may not be sustainable. The magnitude and duration of possible effects cannot be estimated without determining precise conditions of available resources in the area and details of these operations.

CUMULATIVE EFFECTS

Impacts to soil from farming and construction activities would continue to occur in the Proposed Mining Area. Farming is the most extensive land use and has impacts similar to the physical, chemical, and biological effects of soil handling operations associated with mining. Construction activities associated with expanding towns, new hamlets, minor roads and trails, and small-scale sand and gravel mining would likely continue within the Study Area, resulting in further disturbance to soil that may or may not be subject to future reclamation. These land use activities' impacts to soil resources would combine with the Project impacts to yield cumulative but unquantifiable effects on soil resources including soil loss, reduced fertility and loss of soil structure.

ANNEX D-9

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; NOISE

ANALYSIS OF IMPACTS TO NOISE AND VIBRATION

DIRECT AND INDIRECT IMPACTS

The Project would increase the general level of noise and vibration near active operations. Mining activities that generate noise and vibrations are classified as follows:

- Continuous or semi-continuous noise produced by haul trucks, heavy equipment (e.g., dozers, loaders, shovels, excavators, etc.), excavation equipment (e.g., drills, grizzly screens, jaw crushers, etc.) and processing activities as well as equipment at the plant site (e.g., ball and SAG mills, crushers, loaders, compressors and pumps). Vibration associated with these sources is generally low and localized.
- Intermittent noise, air over-pressure and vibration could result from blasting at the mine pit.

Continuous/Semi-continuous noise

Continuous or semi-continuous noise would be produced by several sources operating in a variety of locations throughout the Proposed Mining Area. Most of the noise, however, would come from three major activities: excavation in the pit, processing at the plant site and the dumping of waste rock.

Mine Pit - Excavation in the mine pit would require use of relatively loud equipment including drills, excavators, loaders and grizzly screens. Although operation of this equipment would be expected to result in high levels of noise very near the equipment, the equipment would typically operate in a pit below the elevation of the surrounding ground. Therefore, the pit walls would act as an intervening noise barrier, which would reduce noise from equipment at distant receivers. The highest potential for noise impacts from sources operating in the pit would occur at early stages of mining activity, before the pit is lower than the surrounding area.

Plant Site - Numerous noise sources are located at a mine processing plant site. Major noise sources at the plant site include a ball mill, SAG mill, several rock or pebble crushers, slurry and screens, several large generators and front-end loaders. Secondary noise contributors could include various compressors and pumps, gold processing equipment, smaller mobile equipment and vehicles, conveyor systems and transformers at the plant site power substation.

Waste Rock Disposal Facilities - After rock is blasted, ore and waste rock are sorted and waste rock transported to waste rock disposal facilities adjacent to the mine pit. Noise from this activity typically includes transporting material to upper elevations of the waste rock disposal facilities via haul truck and dumping waste rock. Haul truck dumping activity often includes noise from revving the truck engine to lift the truck bed and impact noise from the dumped waste rock striking other rocks. The waste rock disposal facilities would increase in elevation as mining progresses, and truck travel routes and dumping locations

gradually become more elevated. The greatest potential for noise impacts from this activity occurs after the dumps have increased in elevation to a point where there is little to no intervening terrain or vegetation between the dumps and any nearby residential receivers.

Table D9-I lists the types and quantities of equipment that were assumed to be operating in the mine pit, processing plant and waste rock disposal facilities. Sound levels of the equipment were assigned to each piece of equipment using published information in conjunction with measurements of operations at Newmont's Ahafo mine (Geomatrix 2007d).

Area	Equipment	Source	Quantity	Leq(dBA @ 15m)	Usage Factor(%)	Hourly Leq (dBA @ 15m)
Mine Pit	Bulldozer	1	2	82	80	84
	Fuel Truck	2	1	76	40	72
	Tractor	2	1	84	40	80
	Pickup truck	2	5	75	40	78
	Pit Drill	5	2	85	50	85
	Haul Truck Empty	5	4	84	50	87
	Haul Truck Full	5	4	80	50	83
	Pit Loader + Trucks	5	2	80	50	80
Processing Plant	Pumps	3	2	65	100	68
	Generators	4	2	90	100	93
	Pickup Truck	2	4	75	40	77
	Pebble Crusher	5	1	83	100	83
	Sag and Ball Mills	5	1	87	100	87
	Slurry and Screens	5	1	84	100	84
	Primary Crusher	5	1	69	100	69
	Primary Crusher Feed	5	1	73	100	73
Waste Rock Disposal Facilities	Rock Ore Dump	5	1	89.1	50	86

Source References

- 1: Geomatrix Consultants equipment sound level library
- 2: FHWA Roadway Construction Noise Model, Measured Values
- 3: Noise Control for Building And Manufacturing Plants
- 4: Cummins Model QSK60-G6 1.74 mw Generator Specification Sheet
- 5: Geomatrix (2007d)

Noise levels from mining operations were predicted for locations at the five population centres nearest the mine and more generally at various distances from the mine activities.

For the noise predictions at the five population centres nearest the proposed mine (Mamanso, New Abirem, Afosu, Ahausena, and Hweakwae), the distance from each source to each village was measured using digital maps. Barriers, such as ridges and hills, were considered by analyzing the line of sight from each noise source to each village. Sound levels (dBA) from each major operation were predicted in each village using the methods prescribed by American National Standards Institute 9613-2. This method estimates sound

levels at a receiver location (i.e., village) by extrapolating the sound emission levels of each piece of equipment, considering the effects of distance, atmospheric absorption, and terrain. The resulting sound levels at the villages are presented in **Table D9-2**.

Location	Predicted Noise Level From Proposed Project (dBA)
Mamanso	40
New Abirem South	44
New Abirem North	46
Afosu	46
Adausena	40
Hweakwae	44
Ghanaian Residential Noise Guideline for Nighttime Operations	48

Note: The predicted levels shown above are based on assumptions regarding the types, quantities, and sound levels of equipment proposed for the Akyem mine and include activities and equipment from the excavation pit, plant site, and waste rock dump only. The predicted levels do not include noise from blasting.

Source: Clear Creek Consultants (2007)

For the general estimates of sound levels at various distances from each of the major mining activity areas, distance attenuation was the primary source of noise reduction, with the following exceptions:

- For long-term, continuous activities in the mine pit, a 15-dBA reduction was included in all calculations to account for assumed intervening terrain provided by the pit walls.
- For long-term, continuous activities at the processing plant site, sound levels were calculated with and without a potential 15-dBA reduction due to intervening terrain. Because of the location of the plant site, it is likely that most residential receivers in the mine vicinity would experience this reduction, though not all. Sound levels both within and without the 15-dBA reduction are shown in **Table D9-3**.
- For long-term, continuous activities at the waste rock dump, sound levels were calculated with and without a potential 15-dBA reduction due to intervening terrain. While it is likely that many residential receivers would not experience this reduction, some would. Sound levels both with and without the 15-dBA reduction are shown in **Table D9-3**.

As shown in **Table D9-3**, noise from the mine pit excavation activities is estimated to be 41 dBA at 500 metres from the rim of the mine pit. This level would fall well below the Ghanaian night time residential noise guideline of 48 dBA and is not expected to result in noise impacts to isolated residents 500 metres or greater from the pit.

Noise from equipment at the plant site could exceed 64 dBA at any dwelling within 500 metres of the plant equipment if there is no terrain intervening between the plant site and the dwelling. However, there is likely to be intervening terrain between the plant site and most isolated residences in the vicinity, and the sound level at dwellings farther than 600 metres from plant equipment and with intervening terrain is estimated to be 48 dBA or less.

TABLE D9-3				
Estimated Noise Levels at Various Distances from Source(s)				
Activity/Area	Equipment / Noise Source(s)	Noise Level at Receiver		
		0.5 km	1.0 km	1.5 km
<i>Short-Term, Continuous or Semi-Continuous Noise</i>				
Construction ¹	Three pieces of earth moving equipment operating simultaneously, such as end-dump trucks, bulldozers, scrapers, front-end loaders, and graders.	55 dBA	49 dBA	46 dBA
Reclamation ¹	Three pieces of earth moving equipment operating simultaneously, including end-dump trucks, bulldozers, scrapers, front-end loaders, and graders.	55 dBA	49 dBA	46 dBA
<i>Long-Term, Continuous or Semi-Continuous Noise</i>				
Mine Pit	Listed in Table D9-1.	47 ²	41 ²	37 ²
Plant Site	Listed in Table D9-1.	49 / 64 ³	43 / 58 ³	40 / 55 ³
Waste Rock Disposal Facilities	Listed in Table D9-1.	41 / 56 ⁴	35 / 50 ⁴	31 / 46 ⁴
<i>Long-Term, Intermittent Noise</i>				
Blasting in Excavation Pit ¹	10 charges of 375 lb explosives detonated simultaneously.	120 dBC (peak)	114 dBC (peak)	108 dBC ⁵ (peak)

Notes:

¹ Source: USDOT (1995); Greene and Greene (1997)

² The predicted sound levels include an assumed 15-dBA reduction due to intervening terrain provided by the pit walls.

³ The levels shown are with / without a 15-dBA reduction due to intervening terrain. While some residential receivers may experience little to no reduction due to intervening terrain, it is likely that most residential receivers in the mine vicinity would experience at least a 15-dBA reduction due to terrain.

⁴ The levels shown are with / without a 15-dBA reduction due to intervening terrain. Due to the elevation of the waste rock dump, it is likely that many residential receivers in the mine vicinity would not receive much, if any, reduction due to intervening terrain. However, some residential receivers in the mine vicinity are likely to experience some reduction due to terrain.

⁵ Blast noise potentially audible for several kilometres (km).

Near the waste rock disposal facilities, haul trucks dumping waste rock could produce sound levels exceeding 48 dBA at residences within approximately 1,200 metres of the dump site where there is a clear line-of-sight to the dumping activity. According to both the Ghanaian EPA and WHO guidelines for residential areas, sound levels exceeding 48 dBA would constitute a noise impact during nighttime hours. Because all mine site activity is expected to occur 24-hours a day, noise impacts could occur at dwellings within 600 metres of the plant site (assuming intervening terrain is present), within 1,200 metres of the waste rock disposal facility (assuming no intervening terrain), or within 400 metres of mining activities (assuming reduction due to pit walls), using the assumptions stated above.

Short-term noise levels during construction and reclamation activities are predicted to be 55 dBA at 0.5 kilometres from the Proposed Mining Area (**Table D9-1**). Short-term noise levels during construction and reclamation activities are not predicted to exceed acceptable levels beyond a 0.5-kilometre radius, if they occur during daytime hours (i.e., between 0600 and 2200 hours).

In summary, the relative remoteness of the Proposed Mining Area and plant site from the population centres/villages and the existence of intervening terrain indicate that noise would not be an issue in the most densely-populated areas. However, areas directly surrounding the Proposed Mining Area that are still sparsely populated may be subject to noise levels higher than the Ghanaian EPA noise guideline for residential areas of 48 dBA, which may result in noise impacts.

Intermittent Blasting Noise and Vibration

The predicted peak blasting noise level of approximately 120 dBC at 0.5 kilometres from the Proposed Mining Area (**Table D9-3**) is less than the U.S. Army guideline for human annoyance of 122 dBC. The blast noise could be audible at many locations within approximately a 5-kilometre radius.

Vibration induced by blasting would be minimised because controlled blasting technology would be applied. Also, all private buildings and infrastructure within 500 metres of the planned ultimate pit rim would be relocated. Although blasting noise, air over pressure, and vibration near the mine pit may be noticeable and temporarily disrupt residential activities, relocation of dwellings within 500 metres of the mine pit rim to locations farther from the pit would ensure that no health or safety issues occur.

The prediction of ground vibration levels from blasting that would be experienced in the villages surrounding the proposed mine requires information regarding the blast design, as well as the type of geological strata that exists between the pit and the villages. The most critical blast design element is the charge weight of explosives per delay. The manner in which ground vibrations travel through the geological strata are, ideally, obtained by conducting small test blasts.

The best empirical data regarding blast vibration impacts in the area were collected in conjunction with development of the Company's Ahafo mine in the Brong Ahafo Region. The blast design at the two mines would be similar, as is the geology.

The nearest community to the mine pit is Afosu; portions of community are within 1,250 metres of proposed pit. This distance is similar to the distance from the Ahafo Mine Pit that project's vibration measurement location SKBMP2. Of over 70 blasts monitored at location SKBMP2, the ground vibration levels ranged from 0.0 to 2.2 millimetres per second. Two blasts produced ground vibration levels of 2.2 millimetres per second, while all others produced velocities of less than 2.0 millimetres per second. All measured levels are well below the Ghanaian standard of 5 millimetres per second.

It is unknown what vibration impact that blasting associated with proposed mine pit development would have on individual structures closer than the 1,250 metre analysis presented above.

CUMULATIVE EFFECTS

Noise from the mine is predicted to result in increases in the lowest ambient sound levels (L90s) at locations within several kilometres of the mine activities. However, little to no increase would be expected over the highest existing ambient sound levels currently experienced in the Study Area.

ANNEX D-10

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; HERITAGE RESOURCES

ANALYSIS OF IMPACTS TO HERITAGE RESOURCES

DIRECT AND INDIRECT IMPACTS

Sacred sites and cemeteries are important in terms of linkage with ancestors. Disruption of such sites and relocation of graves would occur as a result of Project development. Preliminary findings of the 2008 supplemental Heritage Resources Survey (Geomatrix 2008d) indicate a total of 46 heritages sites are present in the Study Area. Of these, 18 were attributed by the survey team as Community Sacred Sites (sites which serve the community and are overseen by the stool chief, linguist and / or elders); 12 were Individual Sacred Sites (sites which are located in an individual's home or land and overseen by that individual); six were Royal Cemeteries; and 10 were Public Cemeteries.

Of the 46 heritage sites, 15 sites were determined to be within the Proposed Mining Area where planned development of pits, waste rock disposal facilities and other proposed mine features may impact some or all of the sites. The shrine located in Ayesu Zigah hamlet is well known and revered throughout Ghana. This hamlet would be resettled and the shrine would be relocated as part of that process. The Community Sacred Sites and the other Individual Sacred Sites would be relocated as would the two cemeteries located in Yayaaso. Associated impacts include:

- Destruction of sacred sites and removal of graves could lead to a loss of infrastructure around which to conduct religious activities.
- Sacred sites and graves are closely related to the authority of the ancestors, which contributes to the ideology of household and community organisation in the Study Area. Disruption of these sites may affect social stability and increase potential for social tension within the community.
- Knowledge pertaining to ancestors and forms of behaviour and rituals appropriate to tradition is largely possessed by older generations. Rituals of placation or regular activities of honoring ancestors are performed by specific traditional leaders in the community (most commonly, the chief and linguist). Disruption of these sites could displace the ideology around ancestors and forms of authority endorsed by the ancestors, thereby undermining the position of elders within the family and community.
- Based on ancestral beliefs negative events within communities could easily be rationalized as anger wrought on communities for the developer's inappropriate or disrespectful actions – particularly in regard to sacred sites and graves.

Information has been collected by the Akyem Gold Mining Project Community Relations team about taboo days and their potential effect on proposed mine development. During the 2008 field surveys (Geomatrix 2008d), Ghanaian study team members emphasized that libation ritual would need to be performed to gain permission to continue operating through these days (particularly on the River Pra).

CUMULATIVE EFFECTS

Predicted effects of the proposed Project are not expected to combine with any other existing or proposed activities to result in additive impacts to heritage resources.

ANNEX D I I

DIRECT, INDIRECT AND CUMULATIVE IMPACT ANALYSIS; SOCIOECONOMIC RESOURCES

ANALYSIS OF IMPACTS TO SOCIAL AND ECONOMIC RESOURCES AKYEM GOLD MINING PROJECT

DIRECT AND INDIRECT IMPACTS

Construction and operation of the Project would impact the socioeconomic conditions in Ghana, Birim North District, Study Area, and the Proposed Mining Area creating new wealth by royalty distribution and new job opportunities. Implementation of the proposed Project would also include unavoidable loss of agricultural and Ajenjua Bepo Forest Reserve land, and displacement of households.

Specific impacts and potential mitigation measures are identified with additional detailed information available in the Social Impact Analysis (SIA) prepared by CIVA (2005) and the update to that SIA (GRRL 2008). The SIA impact analyses are issue-based, addressing issues which were generated both via the examination of available documentation and from the SIA and associated field work, including qualitative interviews with local residents, focus groups with local interest groups and key stakeholders, and interviews with local authorities and relevant organisations. In addition, information and specialist (both EIA and SIA team members, OICI, rePlan, Newfields, and SOS International) knowledge accumulated during other similar work in Ghana, the Study Area and elsewhere have contributed to this impact assessment.

Loss of Land

Implementation of the proposed Project would result in temporary impacts to 1,903 hectares (total Proposed Mining Area), of which approximately 1,752 hectares are currently used by area residents for cultivation of cocoa, oil palm, citrus, maize, cassava, plantain, and cocoyam. Approximately 2,734 farm holdings belonging to 242 households living within the Proposed Mining Area and 1,443 households living outside the Proposed Mining Area but farming in there would be temporarily lost during mine development and operation. All of these people would be compensated and would lose the farms, at least temporarily. Some individuals would be able to continue farming on areas designated as controlled farmland. Access to land and resources is of critical importance to sustaining the livelihoods of communities that are predominantly subsistence based and vulnerable as a result of poverty and their relative isolation from income generating activities.

Re-establishing farm fields and relocating Yayaaso and affected hamlet and farmstead residents would reduce the amount of available land and increase pressure on the forest reserves as sources of agricultural land. Productivity on existing land would need to increase in order to avoid undermining local food security.

Most people living in the affected settlements (both directly affected – Yayaaso and hamlets, and indirectly affected – the remainder of the Study Area settlements) receive little cash income and are therefore almost completely reliant on subsistence agriculture for survival. The limitation of access to existing fields and other natural resources as a result of mine development would directly impact those relying on food production within the Proposed Mining Area irrespective of the type of land-use rights held by the land user. The threat to

food security and thereby to people's survival, would begin when land is expropriated and continue until reclamation is complete and land made available to residents or until such time as alternative agricultural land, of equal productivity, is accessible to affected land users.

Local residents would be affected by temporary, and in some cases permanent, elimination of resources growing wild in the Proposed Mining Area. Access to land and resources by people currently living and farming in areas that become host sites for resettlement would also be affected.

Elimination of agricultural fields and subsistence produce would place increased pressure on women to fulfil their expected role within the household, while simultaneously reducing their ability to do so through reduced access to agricultural land (CIVA 2005).

Loss of Land Tenure

Land tenure for populations directly affected by resettlement on the Project is tenuous – given that land was allocated to them through the generosity of the stool chief. However, gaining access to new land places these people at the discretion of the stool chief – even if negotiations for land are done through the Company. These residents would become “settlers” on host land and may be at some disadvantage depending on the specific nature of new tenure arrangements negotiated as part of the resettlement and compensation packages. Those not owning land, but sharecropping or tenant farmers, are at additional risk and need particular attention during compensation negotiation.

Many landowners and users from established settlements have historical attachments to ancestral land dating back to the beginning of settlement in the area (up to 300 years ago). For these residents, the land is seen as a birthright and future inheritance that partially secures survival. People's identity and sense of belonging is often expressed in relationship to ownership of land in the area. Loss of these ties to ancestral land could impact people's sense of self and identity (CIVA 2005).

Detailed information on the additional land use impacts are presented in the SIAs (CIVA 2005 and GRRL 2008).

Loss of Forest Reserve Land

Development of the open-pit mine would permanently remove 74 hectares of existing ethno-botanical resources (wild food products, medicinal plants, firewood) from the Ajenjua Bepo Forest Reserve. In allowing use of part of the Ajenjua Bepo Forest Reserve, the national government is recognizing the transfer of value from one national asset into another. Extraction of gold for export would transfer the Ajenjua Bepo Forest Reserve's natural value into an economic one.

Some survey respondents highlighted the Ajenjua Bepo Forest Reserve as their inheritance – something connecting them to their ancestors. For these individuals the loss of land within the Reserve would have an emotional impact. Although most residents did not express any particular attachment to the forest, its visible presence as part of the natural landscape would be lost, and this loss may affect people's sense of place and identity.

Resettlement

Yayaaso is the only settlement within the Proposed Mining Area. Multiple hamlets and numerous farmsteads are located within the Proposed Mining Area. There are an estimated 1,331 persons (242 households) within the Proposed Mining Area that would be physically displaced by the Project.

There are currently 12 kiosks, two drinking spots, one chop bar, one distilling shed, and four carpentry shops in the Proposed Mining Area that would be displaced. The following public and private facilities would be displaced by the Project and have been identified for compensation and/or relocation:

- Two oil palm processing facilities,
- Two corn mills,
- One marketing shed,
- Primary school serving 100 students from Yayaaso and several hamlets,
- Water tower at Yayaaso and
- Two churches - Pentecost and Mosama.

Residents of Yayaaso and the various hamlets are among the most impoverished in the Study Area, and are further marginalized in regard to long-standing land ownership and traditional attachments to the land. Yayaaso has been settled for nearly 100 years, and the hamlets for at least 75 years. Although these residents are often perceived as “settlers” on Adausena land, they have established attachments to their settlements and fields over this period.

Resettlement involves moving a community or household to an alternate site developed by the Company; *relocation* provides monetary compensation to an affected household to move to a location of their choice; *compensation* provides money for crops and/or structures destroyed at an agreed upon rate between the Company and affected person(s) and in-kind support to enable establishment of alternative livelihood and long term food security. (The Company does not plan to provide cash specifically targeted at short term food security. The Company would implement a programme designed to identify, monitor and support, as necessary, those that need assistance.)

The World Bank identifies the following risks of resettlement for affected communities:

- **Conflict:** This can happen within established communities as existing social structures are disrupted and undermined through resettling, but can also happen between resettlement communities and neighbouring ones. Yayaaso would be an example of potential for conflict during a resettlement. The settlement’s residents are poor, and considered as “settlers” by others in the Study Area. At resettlement these people would suddenly have improved housing and infrastructure, potentially causing envy and conflict with other Study Area settlements.
- **Homelessness:** Relocation is often given as an alternative to resettlement. Experience suggests that people make short-term decisions with their cash and often end up without either the money or the security of a home and therefore become vulnerable. Considering the “settler” perception that people have of Yayaaso

residents and the sense of impermanence of the hamlets, the possibility of people opting for relocation would seem high. Under these circumstances people would be provided complete information on which to base decisions.

- **Food security:** For people living a predominantly subsistence lifestyle, moving off the land makes food security an important risk. Both Yayaaso and affected hamlets are almost exclusively subsistence agriculture based. Survival is dependant not only upon crops planted each season but also on the produce of trees (e.g. oil palm and citrus) that need time to be reestablished. The timing of resettlement according to planting and harvesting seasons would assist in securing adequate food supplies – although it is critical that the developer plans to have supplementary food accessible to ensure food security.
- **Impact on host communities:** Land used for resettlement is usually within or adjacent to existing communities – creating social impacts that go beyond the resettled communities. Changes to existing social structures that may result from the presence of a new neighbouring group are impacts that need to be recognized and mitigated in the same way as those experienced by the directly affected communities.
- **Environmental impact:** Establishing a new settlement, with the necessary infrastructure and buildings may mean new environmental impacts on the host area. These need to be recognized cumulatively taking account of neighbouring communities and available resources.
- **Increase in social pathologies** – alcoholism, crime, prostitution: Changes in social structures and known lifestyles often have correlating emotional and psychological consequences. Additional emphasis should be given these impacts in the resettled community and measures to address them should be discussed during resettlement planning stages.

Given the extent of the impact of involuntary resettlement of communities and considering international best practice, the Company has commissioned a Resettlement Action Plan, which aims to mitigate impacts through a comprehensive plan for resettlement and compensation that would be identified and implemented in a participatory manner. Detailed discussions of resettlement and compensation would be described in the Resettlement Action Plan.

Detailed information on the additional resettlement impacts are presented in the SIAs (CIVA 2005 and GRRL 2008).

Population Movement

As a result of development of the Project, the resident population in the Proposed Mining Area would drop to zero as a result of resettlement and relocation, and it is foreseen that the current residents of the Proposed Mining Area would become part of adjacent resettlement communities.

An in-migration of construction and operations workers would be anticipated to compete with local residents for employment. Local residents may find themselves dealing with social problems such as prostitution, teen pregnancy, drugs, drunkenness, and increased crime

Prostitution is recognized as an unavoidable consequence of a large influx of wealth, which, aside from the health implications discussed below, tends to create conflict between spouses, sometimes with breakdowns in marriage and disruption of families and children.

Potential impacts would include inflation of local food and accommodation costs; a decrease in the availability of food and accommodations; an additional burden on an already inadequate infrastructure, especially sanitation and solid waste disposal; and further stress on marginal water resources, health care facilities, and schools. Currently (before authorization is obtained to develop the Project), local salaried professionals such as teachers and medical workers report that housing costs have increased beyond their ability to pay (CIVA 2005).

Outsiders who fail to find employment may resort to criminal activities. In addition, there is increasing Galamsay (illegal, artisanal mining) activity in the region – about five kilometres northeast of Afosu a settlement has grown from 10 people to over 1,000 in a number of years. While not an impact of the Project per se, the presence of Galamsay could have an effect on local settlements. As the settlements around the Project Area swell with the influx of job seekers and expand the services they supply and products they sell, they would likely attract the Galamsay, many of whom are armed and have been described as aggressive.

One of the concerns expressed by health workers at the New Abirem Centre was the enormous increase of accommodation costs as a result of the presence of the Project. Rates for accommodations have risen from GH¢1 to GH¢2/month (\$0.97 - \$1.94 USD) for a single room to GH¢5 (\$4.85 USD). This monthly rate, combined with a typical 3 month deposit up-front, makes it difficult for non-mine employees to afford rental accommodation (GRRL 2008).

Social System

The Study Area currently is an agriculturally-based rural society. Social systems and structures have evolved in the Study Area over generations and have responded dynamically to the changing social environment. Any development of the scale of the proposed Project would mean social change, particularly as residents in the Project Area would be resettled and the population of the Study Area would experience a change from an agricultural to an industrial environment.

The influence of the Project on the various intra- and inter-settlement social systems and structures would likely be experienced in a number of ways. Kinship relationships as well as economic and social sharing of resources are common, providing support (emotional and practical) between residents of the Study Area. It is vital that people (vulnerable population groups in particular) are not left worse off as a result of the Project.

Changes in well-being are often difficult to identify because they cannot easily be measured. People's uncertainty regarding the future; unfulfilled expectations for individual and family lifestyle improvements; and alteration and/or breakdown of social bonds and support mechanisms could impact the well-being of affected individuals, households, and communities. The extent of the impact may vary from person to person depending on the support structures they have access to. In addition, impacts of resettlement could

compound emotional stress and contribute to reduced well-being among affected individuals and their families. Decreased emotional well-being could also lead to alcohol abuse and increased incidences of family violence.

Challenges to Traditional Authority

The Paramount Chief at Akyem Oda is the head of the Kotoku Traditional Area. Below him are the various divisional chiefs who exercise traditional authority over the chiefs, sub-chiefs and headmen administering the communities and stool lands within the Paramountcy. At the community level the chiefs, sub-chiefs, and headmen, in consultation with their elders, typically resolve issues and conflict and are in most cases the symbol of unity and custodians of the customs and traditional practices of the community.

With the influx of people from other areas of the country and from other cultures, this traditional role could come under threat. The transition from agrarian economy to a more industrial, urban economy could also lead to an undermining of the role of these traditional rulers.

Ethnic Diversity

Mine development would likely create an influx of people to the area in search of work and spin-off opportunities. In-migrants would bring ethnic and racial diversity to the area and facilitate an expanded world-view that local people, most of whom rarely travel, would otherwise not experience. Diversification of ethnicity would be positive and inter-tribal marriages would create an opportunity for national unity and tolerance (CIVA 2005).

The influx of “different” people may also increase levels of conflict through misunderstandings or tribal and community loyalties, which may feel threatened. This would create the positive diversity referred to above, but could also create tension both around perceptions of outsiders accessing jobs and around the short-term presence of contractors in the area. Short-term contracts have, across numerous international projects, often correlated to contractors with no need or desire to integrate into local society, and this lack of a sense of belonging, in conjunction with the reality of contractors being single men far from home and family, may result in unaccountable social behaviour with little regard for the consequences of inappropriate actions.

Vulnerable Populations

Within the Study Area, the most marginalized groups are those whose access to land and food produced thereon depends on other people. This group includes sharecroppers and tenant farmers. Women for whom access is dependant upon a husband or male family member owning land may also be classified as vulnerable. In addition, where men would be lost to the family’s agricultural activities because of mine employment, food security could be threatened, increasing vulnerability of this group. If salaries are spent on food (thereby replacing lost productivity) food security would then be guaranteed. A last group vulnerable to loss of land is the youth who would not gain compensation for loss but would also not have future access to land that is their inheritance.

Malaria

Malaria is the most frequently occurring disease in the Study Area (CIVA 2005). The development of a water storage facility may lead to increased malaria vectors in the area, thereby increasing the risk of infection within local communities and Project accommodation villages.

Malaria requires institutional capacity (and some financial input) to undertake preventative programs. There are various studies by malaria specialists from the South African Institute of Medical Research, as well as environmental economists from the NGO Africa Fights Malaria, to ascertain the impacts of malaria on heavy industry and mining in Mozambique and Zambia. All these studies conclude that the disease has an impact on productivity in the form of downtime, treatment costs, and costs of preventing the spread of malaria (CIVA 2005).

HIV/AIDS

HIV/AIDS are seen as critical issues in Africa with disastrous consequences. The disease follows transport corridors and spreads rapidly in Proposed Mining Areas where there is an influx of migrant workers. The incidence of HIV/AIDS could increase as a result of immigration of workers seeking employment. At present the HIV/AIDS infection rate in Ghana is approximately 3 percent, making it one of the lowest rates in Africa. The New Abirem Health Centre reported that the incidence of HIV is not high (although the stigma attached to HIV/AIDS would contribute to non-disclosure thus probably reducing diagnosed cases) but sexually transmitted diseases are prevalent.

Detailed discussions of the additional impacts on social systems and the population are included in the SIAs (CIVA 2005 and GRRL 2008).

Economics

Ghana is a member of the Heavily Indebted Poor Countries program. A Foreign Direct Investment project such as the Project is recognized as a way of reducing the country's debt, increasing the Gross Domestic Product, and potentially reducing the levels of poverty in the country.

The Project would function as a “basic industry” in Ghana, the Birim North District, and Study Area economy. “Basic industries” are those business and government activities, which bring outside income into an area economy. Through salaries and purchases with non-local monies in local economies, provides a foundation for economic development at the national, district, and Study Area levels.

Gold recover at the mine site is predicted to be in excess of 7.7 million ounces over the 17-year life-of-mine. At the national level, the Project would have a direct impact through the payment of royalties and taxes related to gold production and Company profits, and an indirect positive impact through additional income taxes on the increase in direct and indirect employment; increased incomes and profits of local businesses and major suppliers; and the purchase of goods and services manufactured and supplied in Ghana.

Taxes and Royalties

The Investment Agreement between the Company and the government of Ghana defines and fixes the effective tax and royalty burden the Project would carry during construction and operation. In Ghana, mining companies pay royalties to the central government for the extraction of minerals from territorial land. For the Company, the royalty payment 3 percent of gross sales with an additional 0.6 percent royalty of gross sales attributed for mining within the forest reserve. The Company would pay this royalty quarterly to the Internal Revenue Service as stipulated in the Company Investment Agreement.

Employment Opportunities

Labour for construction of the Project, based on the Ahafo experience, is estimated to average 1,750 workers and to peak at 3,300 workers over the 30-month construction period. Five hundred employees will work for NGGL directly. The short-term employment mix of contract workers at any one time is expected to include:

- 500 skilled from primarily outside of the Study Area,
- 250 semi-skilled from within the Study Area and
- 500 unskilled – from within the Study Area.

In addition, approximately 130 employees would be required for security purposes and 80 percent (104 workers) of these would be selected from residents currently living within the Study Area.

The anticipated workforce, once mining operations begin, would range between 2,800 and 3,300 workers. Between 1,300 and 1,500 of those workers would be employed directly by NGGL for administrative, technical, and mining jobs. Between 1,500 and 1,800 would be contract labour hired to provide laboratory, vehicle and equipment maintenance, catering, and transport services. Both NGGL and contractors would hire between 25 and 35 percent of their labour from the local communities, resulting in between 700 and 1,155 jobs for local residents during operations. **(Table D-11-1)** The employment mix would include approximately 100 expatriates.

	NGGL	Contractor	Total Employment
Total Employment	1,300 – 1,500	1,500 – 1,800	2,800 – 3,300
25% Local local	325 - 375	375 - 450	700 - 825
30% Local local	390 – 450	450 - 540	840 - 990
35% Local local	455 – 525	525 -630	980 – 1,155

Expatriate numbers would reduce as the Project progresses and Ghanaian staff would replace expatriate supervisors and managers. In an environment where only 12 percent of residents in the Study Area report having access to formal employment these new jobs would bring significant benefit to the area. In addition, the number of job opportunities would significantly decrease the household dependency ratios.

Although the local communities expect that the Project employs its entire required workforce (skilled and unskilled labour) from the affected communities, some technical skills required for the operation cannot be obtained from the communities. Therefore, it is foreseen that the Project would aim to employ 100 percent of the unskilled labour from the affected communities while aiming to maximize skilled labour employment. By way of comparison, the Ahafo project has committed to employing 30 percent of the total permanent workforce from the local communities.

Ghanaian Labour Law sets a minimum employment age of 15 years and prohibits night work and certain types of hazardous labour for those younger than 18; however, child labour is a serious problem in the informal sector. Many parents in the District engage their school-going age children in the family farming enterprises, as well as other businesses. This is due to poverty that precludes some families from hiring labourers. It is also common to see children selling goods on the streets at the expense of their education. The Project would ensure a minimum age for employment within the Project of 18 years in accordance with both Ghanaian and International labour laws.

Indirect Employment

The normal job creation multiplier for local service industries in the gold mining industry ranges from 3 to 6 indirect jobs for each direct NGGL employee (SGS 2000). Other sources state this multiplier effect could be as high as 10 indirect jobs resulting from each direct job (Chamber of Mines of South Africa 2005).

The construction phase of the Project is expected to create a sustained average of 1,750 new jobs, of which 500 workers would be permanent NGGL employees. Given the range of 3 to 6 indirect jobs (including the contractor created jobs) created for every new direct job, an implied range of between 250 to 1,750 additional indirect jobs could be created.

The operational phase of the Project is expected to require a mix of staff ranging from 2,800 to 3,300 employees. Between 1,300 and 1,500 workers will be employed directly by NGGL. Indirect employment (calculated on Company employees only) may range from 2,400 to 7,200 additional new indirect jobs.

Purchases of Goods and Services

In addition to direct employment opportunities with the Company and its contractors, several hundred new jobs would be created to service the needs of local mine employees and their families. Currently there is limited local and perhaps national capacity, to supply the Company's needs. The Company policy to procure locally can improve the income levels, increase entrepreneurial capacity, and broaden potential markets, all of which enables the local economy to reduce long term dependence on the mine. If the Company has to import most supplies from outside the area, it could create conflict over benefits leaving the area.

It is difficult to estimate the dollar amount of procurement for goods and services that would actually occur with the exception of electrical power from the VRA. Average expenditures per year for electrical power required for oxide and primary ore processing

range from approximately \$18.6 to \$21.3 million (USD). Payments would be received by VRA and are sensitive to the final conditions of the Power Purchase Agreement Contract negotiated between the Company and VRA.

Other procurement opportunities would depend on goods and services available in the Study Area, the district, and in Ghana.

Potential for Inflation

CIVA 2005 notes that increased opportunities create economic risks at the local level. Inflated housing and food costs may create increased hardship for local people especially for civil servants working in the area. Of particular concern is the impact that high rentals are already having on teachers and health workers who are either deployed to the area or enticed by the hope of jobs. However, high living costs threaten to undermine the ability and desirability of staff to work in the area – and as a spin-off, threatens access of local residents to health care and education. This is of particular concern during the construction phase – before Proposed Mining Area accommodations would be completed to relieve the demand on the local housing supply.

Sustainable Development

Economic expansion in the Study Area would occur at relatively rapid rate considering the low starting point. Mining is a finite activity, depending on the extent of the reserve, and the danger of the extraordinary burst of economic growth that results from a project of this nature into a predominantly subsistence agricultural economy is that it may not be sustainable in the future, resulting in a boom and bust effect which may leave residents worse off than before.

Detailed discussions concerning impacts to additional economic activities are contained in the SIAs (CIVA 2005 and GRRL 2008).

CUMULATIVE EFFECTS

The impacts to land use would continue as additional people move to the area to find employment and require accommodation and community services. With full operational development of the concession, the Project would not require any additional land; however, demand for permanent housing and replacement agricultural fields may continue for many years.

Implementation of the proposed Project would set a precedent for mining in forest reserves (a small number of exploration permits are currently being exercised) and this is an impact of cumulative concern at the national and international level.

The social and economic pressures of population growth would continue as additional people move to the area to find employment and require accommodations and community services. With full operational development of the concession, employment and the economic/training improvement benefits streaming from that would continue providing a longer timeframe to create the base for economic security, sustainable development, and social adjustment after closure.