3.0 EXISTING ENVIRONMENT

Existing biological, physical and human resources in the Study Area are described in this section of the EIS. Data and information presented were collected during Company-sponsored baseline studies as well as through review of available scientific literature. Because a portion of the proposed mine pit associated with the Project would be developed within the southern end of the Ajenjua Bepo Forest Reserve, a separate discussion of this resource area is presented. Conditions outside the Ajenjua Bepo Forest Reserve are also discussed and compared and contrasted to those present within the Forest Reserve. Characteristics of other aspects of the Study Area are discussed by resource area for the entire Study Area, focusing on the Proposed Mining Area.

3.1 BIOLOGICAL ENVIRONMENT

The following sections discuss the biodiversity of particular locations within the Proposed Mining Area and Study Area as well as the characteristics of the flora and fauna both within and outside the Ajenjua Bepo Forest Reserve (**Figure 3-1**). Discussions of wetlands and aquatic resources in the broader Study Area conclude this section.

3.1.1 KEY BIODIVERSITY INDICATORS IN STUDY AREA

Several indicators are used in Ghana to assess the biodiversity of resource areas, including:

- Forest Reserve Condition,
- Forest Patch Size,
- Connectedness with other Forest Communities,
- Ghana Wildlife Conservation Regulations (Schedule I),
- International Union of Nature and Natural Resources (IUCN) Species of Conservation Concern (flora and fauna),
- Ghana Star Species (flora) of Conservation Concern and
- Genetic Heat Index.

Another indicator, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), is also sometimes used to evaluate biological aspects of an area. CITES, however, was intended to support regulation of species involved in international trade. Because of this, CITES-listed species are not necessarily the best indicators of biodiversity in the Study Area. Most species regulated under CITES in Ghana also are also included on the IUCN Red List or within the Ghana Wildlife Conservation Regulations.

A description of the foregoing biodiversity indicators and the application of these indicators to particular portions of the Study Area are presented herein.

Figure 3-1

FOREST RESERVE CONDITION

Hawthorne and Abu-Juam (1995) developed a system to evaluate the condition of forest reserves in Ghana. The scale of the system extends from a score of 1 (excellent condition) to 6 (no significant forest remaining). This rating system for forest condition is presented in **Table 3-1**.

TABLE 3-1
Forest Reserve Condition Scores

Score	Description
1	EXCELLENT: with few signs (<2%) human disturbance, with good canopy and virgin or late secondary forest throughout
2	GOOD: with <10% heavily disturbed. Logging damage restricted or light and well dispersed. Fire damage none or peripheral.
3	SLIGHTLY DEGRADED: Obviously disturbed or degraded and usually patchy, but with good forest predominant; maximum 25% with serious scars and poor regeneration; maximum 50% slightly disturbed, with broken upper canopy.
4	MOSTLY DEGRADED: Obviously disturbed and patchy, with poor quality forest predominant; 25-50% with serious scars; maximum 75% disrupted canopy or forest slightly burned throughout.
5	VERY POOR: forest with coherent canopy < 25% or more with half the forest with serious scars and poor forest regeneration; or almost all heavily burned with conspicuous pioneer species throughout.
6	NO SIGNIFICANT FOREST LEFT: Almost all deforested with savanna, plantation, or farm; <2% good forest; or 2-5% very disturbed forest remaining; or 5-10% left in extremely poor condition.

Source: Hawthorne and Abu-Juam (1995)

FOREST PATCH SIZE

The size of intact areas of forest (patch size) is an excellent indicator of biodiversity. Typically, higher levels of biodiversity are associated with larger intact patches of forest. The larger the intact patch of forest, the higher the potential biodiversity values. Larger patches of intact forest provide security of species that are sought for bushmeat and species that are adapted to interior forest habitat. Beier et al. (2002) studied birds in a forest of central Ghana and found that as the size of contiguous forest decreased, species richness of birds decreased.

CONNECTEDNESS WITH OTHER FOREST COMMUNITIES

Throughout Ghana, forested habitats are fragmented and under pressure from logging, bushmeat hunting and gathering of non-timber forest products. Forest patches are often isolated in a matrix of farms and fallow. The potential for animals to move regionally among nearby patches of forest habitat helps maintain genetic diversity and allows interior forest species greater habitat security.

GHANA WILDLIFE CONSERVATION REGULATIONS (SCHEDULE 1)

Species of animals listed under the Schedule 1 of the Ghana Wildlife Conservation Regulations are completely protected. The hunting, capturing or destroying of these species are prohibited at all times. Populations of many of these species in Ghana have been reduced due to illegal bushmeat hunting.

IUCN SPECIES OF CONSERVATION CONCERN

The International Union of Conservation of Nature (IUCN) ranks species of plants and animals throughout the World on their potential for extinction.

A species with the greatest risk of extinction is ranked as "Critically Endangered". No Critically Endangered species of plants or animals have been recorded in the Study Area.

A species is "Endangered" when best available evidence indicates that it is facing a very high risk of extinction in the wild due to:

- Population reduction of 50 to 70 percent over the last 10 years,
- Limited geographic range (less than 5,000 square kilometres),
- Known existence at no more than five locations,
- Population is estimated at fewer than 2,500 individuals and
- Probability of extinction at least 20 percent in 20 years.

A species is "Vulnerable" when best available evidence indicates that it is facing a high extinction risk in the wild due to:

- Population reduction of 30 to 50 percent over the last 10 years,
- Range of occurrence less than 20,000 square kilometres,
- Population size estimated at less than 10,000 mature individuals and
- Probability of extinction is at least 10 percent within 100 years.

A species is "Near Threatened" when it does not qualify for "Critically Endangered," "Endangered" or "Vulnerable" now but is close to qualifying for or is likely to qualify for a threatened category in the near future.

GHANA STAR SPECIES (FLORA) OF CONSERVATION CONCERN

A common method used in Ghana to evaluate floral species density and biodiversity is the "Star" system, developed by Hawthorne and Abu-Juam (1995). Using this system**,** plant species are evaluated on a scale ranging from "Black Star" (rare globally and not widespread in Ghana) to a "Green Star" (species are common and widespread in tropical Africa). **Table 3-2** summarizes this rating system.

GENETIC HEAT INDEX

A common index used to evaluate floral diversity in Ghana is the Genetic Heat Index (GHI) developed by Hawthorne and Abu-Juam (1995). GHI reflects the concentration of rare plant species in an area and allows prioritization of conservation areas. In Ghana, the Wet Evergreen forests and Southern Dry forests typically have the highest GHI values whereas the Moist Semi-deciduous forest zone, including the Study Area, has low to moderate GHI values, even under pristine conditions (Hawthorne and Abu-Juam 1995).

TABLE 3-2
Star Ratings for Plant Species in Ghana

Star Rating	Description
Black	Highly significant in context of global biodiversity; Rare globally and not widespread in Ghana.
Gold	Significant in context of global biodiversity; fairly rare globally and/or nationally.
Blue	Mainly of national biodiversity interest; e.g. globally widespread, nationally rare; or globally rare but of no concern in Ghana due to commonness.
Scarlet	Common and widespread commercial species with potential seriously threatened by overexploitation.
Red	Common and widespread commercial species; under significant pressure from exploitation.
Pink	Common and widespread commercial species; not currently under significant pressure from exploitation.
Green	Species common and widespread in tropical Africa; no conservation concern.
Other	Unknown, or non-forest species e.g. ornamentals or savannah plants.

Source: Hawthorne and Abu-Juam (1995).

ANALYSIS OF BIODIVERSITY IN STUDY AREA

Baseline biodiversity studies conducted in the Study Area surveyed a wide range of flora and fauna species and their habitats (Ghana Wildlife Society 2007; Geomatrix 2008a and 2008b; SGS 1998, 2004a and 2004b). **Table 3-3** summarizes the key biodiversity attributes described above for portions of the Study Area, including (1) the Proposed Mining Area that is outside of the forest reserves, (2) the Ajenjua Bepo Forest Reserve within the Proposed Mining Area, (3) the Ajenjua Bepo Forest Reserve outside of the proposed mine development area and (4) the Mamang River Forest Reserve, which would not be affected by the proposed Project.

Evaluation of the key biodiversity components summarized in **Table 3-3** indicates that the highest biodiversity values in the Study Area are found in the Mamang River Forest Reserve, followed by portions of the Ajenjua Bepo Forest Reserve outside of the areas proposed for mining. The lowest biodiversity values are associated with the matrix of agricultural land outside of forest reserves, followed by the portion of the Ajenjua Bepo Forest Reserve within the area proposed for mine development.

The Mamang River Forest Reserve has the highest biodiversity values because of its large patch size (5,400 hecatres), connectedness with six other forest reserves and relatively intact forest structure (Condition Class 2) that provides habitat for a diversity of forest-dependent plants and animals. The Mamang River Forest Reserve also exhibits the highest GHI of the four areas assessed with an overall score of 91. GHI values within the Study Area (ranging from 31 to 91), however, are relatively low compared to values reported by Hawthorne and Abu-Juam (1995) for the Ankasa Conservation Area and Neung North Forest Reserve, which have the highest ratings in Ghana with average index values of 301 and 269, respectively. The Mamang River Forest Reserve also supports the most mammal species of conservation concern based on IUCN rankings and Ghana Wildlife Conservation Regulations (Schedule 1) (**Table 3-3**).

TABLE 3-3
Summary of Key Biodiversity Indicators in the Akyem Study Area

Key Biodiversity Parameters	Mamang River Forest Reserve	Ajenjua Bepo Forest Reserve Outside of Proposed Mining Area	Ajenjua Bepo Forest Reserve Within Proposed Mining Area	Proposed Mining Area Outside of Forest Reserves
Forest Condition Class	2	3	4 and 6	6
Forest Patch Size(1)	5400 hectares	181 hectares(2)	74 hectares	3 to 5 hectares (estimated)
Connectedness with other Forest Communities	Good condition forest contiguous with six other forest reserves	Isolated forest surrounded by agricultural land	Isolated forest surrounded by agricultural land	Isolated small patches of forest in agricultural matrix
Genetic Heat Index	91	85	44	31
IUCN Fauna Species of Conservation Concern(3)	4 duikers, Bongo, Diana monkey, Black and white colobus monkey, 1 bat, 1 frog, 1 anomalure 1 bird	3 duikers, 1 bat 1 frog, 1 anomalure,	3 duikers, 1 bat, 1 anomalure	3 duikers, 3 bats, 1 anomalure, 1 bird
IUCN Flora Species of Conservation Concern(3)	7 tree species; common and widespread in Ghana	7 tree species; common and widespread in Ghana	7 tree species; common and widespread in Ghana	7 tree species; restricted to fallow areas and cocoa plantations
Ghana Wildlife Conservation Regulations Schedule 1 Species	16 large mammals, 3 birds	8 large mammals, 7 birds	12 large mammals, 7 birds	3 large mammals, 14 birds
Ghana Star Species (flora) of Conservation Concern	3 Black Star species, 3 Gold Star species, 7 Scarlet Star species	3 Black Star species, 1 Gold Star species, 7 Scarlet Star species	7 Scarlet Star species	1 Gold Star species, 7 Scarlet Star species

Notes:
(1) Forest patch size is an excellent indicator of biodiversity. The larger the intact patch of forest, the higher the potential biodiversity values.
(2) Includes only forested areas within the Ajenjua Bepo Forest Reserve.
(3) Species in the Study Area listed by IUCN as Endangered, Vulnerable, and Near Threatened species.
Endangered – Species having a very high risk of extinction in the wild.
Vulnerable – Species having a high risk of extinction in the wild.
Near Threatened – Close to qualifying for Vulnerable status.

The Ajenjua Bepo Forest Reserve has relatively lower biodiversity values (as compared to the Mamang River Forest Reserve) because of its small forest patch size (181 hectares), isolation from other forest reserves, its fragmented condition caused by agricultural development, and its degraded forest of varying quality (Condition Class 3, 4 and 6). The Ajenjua Bepo Forest Reserve is isolated in a matrix of agricultural land while the Mamang River Forest Reserve is interconnected to six other forest reserves.

The 74 hectare area of the Ajenjua Bepo Forest Reserve proposed for mine development has relatively lower biodiversity values than the Mamang River Forest Reserve and the portion of the Ajenjua Bepo Forest Reserve outside the Proposed Mining Area because of its lower forest condition class, smaller forest patch size, and poor connectivity to other

forest communities. It is similar in biodiversity value to the matrix of farm and fallow land in which the majority of the project development would take place, outside the Ajenjua Bepo Forest Reserve.

The Proposed Mining Area outside the forest reserves is largely a matrix of agricultural land and fallow that supports species adapted to human activity. Small numbers of "Vulnerable" tree species are present in cocoa plantations within the Proposed Mining Area outside the Ajenjua Bepo Forest Reserve, providing shade requirements for cocoa plants. Some "Vulnerable" or "Near Threatened" animals (e.g., duikers, birds, and bats) forage in the agricultural/fallow matrix but are dependent on adjacent forest habitats for breeding and security cover.

No "Critically Endangered" or "Endangered" plants have been identified in the Study Area. Seven tree species that occur in the Study Area are ranked as "Vulnerable." No "Critically Endangered" animals have been detected in the Study Area but several species that are present have been ranked as "Endangered," "Vulnerable" or "Near Threatened" (**Table CI-2, Annex C-1)**.

3.1.2 FLORA AND FAUNA WITHIN THE AJENJUA BEPO FOREST RESERVE

FLORA

Established in 1930, the Ajenjua Bepo Forest Reserve is located entirely within the Pra River drainage basin (**Figure 3-1**). The Ajenjua Bepo Forest Reserve is classified as Moist Semi-deciduous forest (Hall and Swaine 1981) with a total area of 569 hectares of which 255 hectares are secondary forest and the remainder is cropland and plantations of non-indigenous trees. Hawthorne and Abu-Juam in 1995 undertook work from which the classification system referred to above was generated, indicating that the overall forest was a Condition Class 4 forest (*Mostly Degraded*) with the best natural forest preserved on a hill located in the northern portion of the Ajenjua Bepo Forest Reserve.

Biodiversity studies of the Ajenjua Bepo Forest Reserve commissioned by the Company have been conducted by SGS (1998, 2004a, 2004b, 2004c, and 2004f), Conservation International (2005 and 2006), and Geomatrix (2008a and 2008b) in conjunction with baseline studies associated with exploration and mining interests in the area.

The initial biodiversity studies focused primarily on 250 hectares of relatively degraded forest comprising the southern portion of the Ajenjua Bepo Forest Reserve as this was the area of primary exploration interest. The initial assessment concluded that the 250-hectare parcel of land being considered for exploration was Forest Condition Class 6 with a small patch of Condition Class 4 forest (*Mostly Degraded*) along the southeast forest boundary.

Additionally, species density and diversity were rated as poor within the target area with no "Black Star" timber species nor any species classified as rare in Ghana. Most plants in the Study Area are Green Star species, common and widespread in tropical Africa and of no conservation concern. The initial assessment of forest biodiversity reached conclusions similar to those of Hawthorne and Abu-Juam (1995) indicating that the overall Forest

Reserve was a Forest Condition Class 4 with the best natural forest preserved on a hill located in the northern portion of the Ajenjua Bepo Forest Reserve, outside of the 250 hectare area permitted for exploration.

Follow-up studies in 2004, 2005 and 2006 to evaluate flora within the wider Ajenjua Bepo Forest Reserve indicated that the condition of the Forest Reserve had not changed measurably from previous assessments (Ghana Wildlife Society 2007; Geomatrix Consultants 2008a and 2008b; SGS 1998, 2004a and 2004b).

Results of various biodiversity studies show that the Ajenjua Bepo Forest Reserve has been extensively logged, converted to cropland (e.g., cocoa, cassava, maize and plantain) and planted with non-native timber species (e.g., *Cedrela odorata*). The structure and composition of plant communities and wildlife habitats have been fragmented and altered by human activities and have little resemblance to natural forests once typical of the region. Several communities are located near the boundary of the Ajenjua Bepo Forest Reserve and local residents access and use the Forest Reserve for bushmeat hunting, farming and gathering of forest products.

Species Diversity

Vegetation in the Ajenjua Bepo Forest Reserve is comprised of secondary forest (255 hectares), Cedrela (170 hectares), cocoa (126 hectares), and food crops (16 hectares). Floral species present in the Forest Reserve include species adapted to disturbed habitats and forest edges.

Economic Value of Timber Species

Economic values of timber species in the Ajenjua Bepo Forest Reserve are reflected in Economic Index values developed by Hawthorne and Abu-Juam (1995). Economic Index values of the Forest Reserve are low (Abu-Juam as cited by SGS 2004a). Economic Index values within the mine footprint in the Forest Reserve are lower and similar to Economic Index values measured outside the Forest Reserve, demonstrating the degraded nature of this portion of the Forest Reserve and its similarity, in terms of Economic Index values, to surrounding agriculturally active lands.

The following species of trees, found within the southern portion of the Ajenjua Bepo Forest Reserve in the vicinity of the proposed mine development are common, widespread timber species in Ghana of economic value (Scarlet Star Rating): *Awiemfosemina* (*Albizia ferruginea*), *Edinam* (*Entandrophragma angolense*), *Penkwa* (*Entandrophragma cylindricum*), *Kusia* (*Nauclea diderrichii), Danta* (*Nesogordonia papaverifera*), *Kyere* (*Pterygota macrocarpa)* and *Emire* (*Terminalia ivorensis)*. These species are also listed by IUCN as "Vulnerable."

Non-Timber Forest Products

Non-timber forest products contribute to providing food, fodder, fuel, medicine, building materials, household items and intangible benefits such as cultural symbols, ritual artefacts and sacred sites for the communities. Such products in the Ajenjua Bepo Forest Reserve include chewing sponge from *Acacia kamerunensis*; firewood and charcoal, mostly from

hardwood species with *Esakoko* (*Celtis zenkeri)* being the preferred species; kola nut from *Bese* (*Cola nitida)*; and wrapping leaves from species in the family Maranthaceae. Studies in the Ajenjua Bepo Forest Reserve have found that about a quarter of the flora potentially provides herbal medicine (Conservation International 2005 and 2006).

Invasive Species

Invasive species are noxious exotic weed species that colonize disturbed sites associated with farming, logging and other factors that remove vegetation cover and alter soil. Noxious weeds proliferate and displace desirable native plant species and increase costs and efforts to convert fallow areas to cropland. Two noxious weeds of most concern are *Siam* or *Acheampong* (*Chromolaena odorata*), introduced from South America, and Devil's teak or York (*Broussonetia papyrifera*, introduced from the Orient. *Acheampong* or *Siam* weed is an aggressive invader that may have properties that inhibit growth of other plant species. *Siam* or *Acheampong* weed is widespread in forest openings where timber has been removed and agricultural land lies fallow. The Devil's teak or York is not yet widespread in the Ajenjua Bepo Forest Reserve.

FAUNA

The various species of fauna present in the Ajenjua Bepo Forest Reserve, as well as outside the Forest Reserve within the broader Study Area are summarized in **Tables C1-1 through C1-5 (Annex C-1)**. Brief discussions of these species and other general attributes of fauna in the Forest Reserve follow.

Characteristics of Fauna

Large Mammals

Biodiversity studies report low occurrences of large mammals within the Ajenjua Bepo Forest Reserve and rare encounters with the 24 species of large mammals identified as present in the Forest Reserve (Conservation International 2005 and 2006). Nineteen species were recorded in the area of the Forest Reserve proposed for mine development. The most widespread species is the grasscutter (*Akrante*). Large mammal species of conservation concern reported within Ajenjua Bepo Forest Reserve in areas proposed for mining are the IUCN "Near Threatened" species including the Maxwell's duiker (*Otwe*), black duiker (*Oyuo*), royal antelope (*Adowa*), and Pel's anomalure (*Otra*). These species are associated primarily with forest habitats but also forage in agricultural land and in fallow re-growth. Species within the Forest Reserve that are protected by CITES are the spot-nosed monkey, putty-nosed monkey, Bosman's potto and bushbaby.

Interviews with local residents and observations concerning large mammals have not indicated use of large mammal species as totems. There is strong evidence of dependence on large mammal species for bushmeat in communities near the Ajenjua Bepo Forest Reserve, which could be a major contributory factor to their low population density.

Small Mammals

Eighteen species of small mammals, other than bats, were recorded in the Ajenjua Bepo Forest Reserve. Nine species were recorded in the area of the Forest Reserve proposed for mine development. Species identified included shrews, squirrels, mice and rats. The most common small mammals are the soft-furred mouse, fire-footed rope squirrel and the zebra mouse. No species of small mammals reported for the Ajenjua Bepo Forest Reserve are of conservation concern based on IUCN, CITES, or Ghana Wildlife Conservation criteria.

Bats

Fifteen species of bats (one insect-eating and 14 fruit bats) were recorded as being present in the Ajenjua Bepo Forest Reserve. Eleven species of fruit bat were recorded for the portion of the Forest Reserve proposed for mine development. Most fruit bats forage and roost in habitats both inside and outside of the Forest Reserve. Plantations of non-indigenous *Cedrela odorata* and *Gmelina arborea,* planted in the Forest Reserve provide seasonally abundant food for some species of fruit bats. The Zenker's fruit bat, round-leaf bat and horseshoe bat are classified as "Near Threatened" by IUCN. All fruit bats identified in the Ajenjua Bepo Forest Reserve are protected under the Ghana Wildlife Conservation regulations.

Birds

Biodiversity studies identified 129 species of birds within the Ajenjua Bepo Forest Reserve. Birds most commonly associated with the Forest Reserve (e.g., turacos, hornbills, trogons, owls, parrots, and most woodpeckers) often have specific habitat or breeding requirements provided by forest habitats. Twenty-two species were recorded for the area of the Forest Reserve proposed for mine development. Some forest species require cavities in large trees for nesting, which are mostly available in forest stands in later stages of ecological succession which are found in the higher quality areas of the Forest Reserve. Eight species are regulated under CITES and 25 species are protected under Ghana Wildlife Conservation regulations. No species ranked by IUCN as of conservation concern have been identified in areas of the Ajenjua Bepo Forest Reserve proposed for mine development.

Reptiles

Biodiversity studies recorded seven species of amphibians and 24 species of reptiles within the Ajenjua Bepo Forest Reserve. Of these, two amphibians and six reptiles were found in the portion of the Forest Reserve proposed for mine development. The green mamba and black cobra are widespread, common venomous snakes. The hinged tortoise, recorded in the Proposed Mining Area, is listed by the IUCN as "Vulnerable." The Nile monitor, hinged tortoise and chameleon are regulated under CITES and the hinged tortoise and Nile monitor are protected under Ghana Wildlife Conservation regulations (Schedule 1).

Butterflies

Surveys identified 129 species of butterflies within the Ajenjua Bepo Forest Reserve. Biodiversity values recorded are typical of moist, deciduous forests and interspersed agricultural land. Several rare and forest interior species of butterflies were identified in the Forest Reserve; however none are identified as having conservation concern.

3.1.3 FLORA AND FAUNA IN THE STUDY AREA

Biodiversity studies of the flora, fauna, wetlands and aquatic resources of the Study Area, outside of the forest reserves, have been conducted over the past several years by SGS (1998, 2004a, 2004b and 2004c), Conservation International (2005 and 2006), Ghana Wildlife Society (2007), and Geomatrix (2008a, 2008b and 2008c). **Annex C-1** contains a list of species that have been recorded in the Study Area.

FLORA

Biodiversity studies found that the area outside of the Ajenjua Bepo Forest Reserve is primarily a complex of agricultural land from which the forest has been removed. The structure and composition of plant communities and wildlife habitats have been extensively fragmented and altered by human activities and have little resemblance to natural forests once typical of the region.

Species Diversity

Land Use Type map (Figure **3-2**) includes cropland, fallow, cocoa, oil palm, citrus, teak, cedrela, secondary forest and wetlands (Geomatrix 2008a). Approximately 4 percent of the Study Area outside of forest reserves is secondary forest and most of the land (96 percent) within the Study Area is cropland and fallow.

Studies conducted outside of the Ajenjua Bepo Forest Reserve identified 339 species of plants. The same seven "Scarlet Star" species of trees identified in the Forest Reserve were also found outside the forest, mostly within fallow areas and cocoa plantations: *Awiemfosaina* (*Albizia ferruginea), Edinam* (*Entandrophragma angolense), Penkwa* (*Entandrophragma cylindricum*), *Kusia* (*Nauclea diderrichii), Danta* (*Nesogordonia papaverifera*), *Keyereye* (*Pterygota macrocarpa)* and *Emire* (*Terminalia ivorensis)*. In addition, one Gold Star tree species, *Kwaebrofre* (*Cussonia bancoensis)*, was recorded in the wider Study Area. This species is not common in Ghana, but occurs in all forest zones and regenerates freely in many areas. Most plants in the wider Study Area are Green Star species, common and widespread in tropical Africa and of no conservation concern.

Agricultural areas reflect various stages of cropping and fallow. The cropping system begins with clearing and burning fallow thickets of secondary forest regrowth. The newly opened fields are then planted with a mixture of food and cash crops that mature at different rates. Typically, production begins with a few years of mixed food crop production including cassava and cocoyam and then proceeds through several years of cash crop production. Fields typically contain a diverse range of crops. Scattered tall trees that emerge from the cropped areas include *Onyina* (*Ceiba pentandra*) and *Wawa* (*Triplochiton scleroxylon)*. As crop

Figure 3-2

fields become less productive, they are abandoned and allowed to revegetate with both native and introduced species. This fallow period allows nutrients to accumulate in soil so that another cropping cycle can be initiated. The period that an area remains fallow depends on the demand for arable land.

Economic Value of Timber Species

The stocking of timber species outside of the forest reserves is low because most of the forest has been removed and replaced by agricultural species. Commercial timber species provide shade for cocoa plantations but these trees are often available for harvesting from cocoa plantations and also when the cocoa plantations are no longer being cultivated.

Non-Timber Forest Products

Non-timber forest products are mostly obtained from the Ajenjua Bepo and Mamang River forest reserves, but fallow areas and patches of forest vegetation outside these reserves also provide some of these non-timber forest products.

Invasive Species

Invasive species are weed species that colonize disturbed sites associated with farming, logging and other factors that remove the natural vegetative cover. They are noxious weeds that proliferate and displace desirable native plant species and increase costs and efforts to convert fallow areas to cropland. Two noxious weeds of most concern are *Siam* or *Acheampong* (*Chromolaena odorata*), introduced from South America, and Devil's teak or York (*Broussonetia papyrifera)*, introduced from the Orient. The *Siam* or *Acheampong* weed is an aggressive invader that may have properties that inhibit growth of other plant species. Both species are present on fallow agricultural land and other uncultivated areas.

FAUNA

Like flora, the fauna of the Study Area outside the Ajenjua Bepo and Mamang River forest reserves has been extensively affected by alteration and fragmentation of habitat resulting from fire, logging, human settlement and agricultural activities. Bushmeat hunting has also reduced numbers and the geographic distribution of many large mammal and bird species, especially those associated with forest communities.

Characteristics of the Fauna

Large Mammals

The Ghana Wildlife Society (2007) reported 15 species of large mammals present in the wider Study Area (**Annex C-1**). The same four large mammal species of conservation concern reported inside the Ajenjua Bepo Forest Reserve are also found in the wider Study Area: *Otwe* (Maxwell's duiker), *Oyuo* (black duiker), Adowa (royal antelope) and *Otra* (Pel's anomalure). Similarly the species protected by CITES are Bosman's potto and bushbaby are also found within the wider Study Area.

Small Mammals

Fifteen species of small mammals were reported within the Study Area outside the Ajenjua Bepo Forest Reserve (Ghana Wildlife Society 2007) including seven species of shrew, four species of squirrel, eight species of mouse and two species of rat. These are widespread species adapted to fragmented habitat. The most common small mammals are the soft-furred mouse, fire-footed rope squirrel and the zebra mouse. No species of small mammals reported for the Study Area are of conservation concern based on IUCN, CITES or Ghana Wildlife Conservation criteria.

Bats

In areas proposed for mining outside forest reserves, 13 species of bats were recorded (six insect-eating and seven fruit bats) (Ghana Wildlife Society 2007). These bats are widespread in West Africa and utilize a range of habitats. Because of their mobility, these bats have been documented in and out of forest habitats. The *Apan* (Zenker's fruit bat, round-leaf bat, horseshoe bat) are classified as Near Threatened by IUCN. No bats reported for the Study Area are regulated under CITES. All fruit bats in the Study Area are protected under the Ghana Wildlife Conservation regulations.

Birds

Biodiversity studies in the Study Area have identified 258 species of birds of which 23 species were found exclusively in the forest habitats, 118 species were found only outside of the forest habitats and 117 species were recorded inside and outside of forest habitats. In areas proposed for mining outside of forest reserves, 203 species of birds were recorded (Ghana Wildlife Society 2007). Birds breeding in habitat outside of the Ajenjua Bepo Forest Reserve are able to adapt to early stages of ecological succession and relatively high levels of human activity (e.g., sunbirds, bishops, weavers, manikins, black kite, and hooded vulture). One species of conservation concern, the rufous-winged illadopsis (IUCN Threatened), was observed in the Study Area, outside of the Forest Reserve. Eight species are regulated under CITES and 25 species are protected under Ghana Wildlife Conservation regulations.

Reptiles

Studies by the Ghana Wildlife Society (2007) found five amphibian species and 20 reptile species in areas proposed for project operations outside of forest reserves. The green mamba and black cobra are common venomous snakes in and out of forest habitats. The hinged tortoise is IUCN "Vulnerable." The Mampam (Nile monitor), hinged tortoise, chameleon, royal python and African python are regulated under CITES and the hinged tortoise and Nile monitor are protected under Ghana Wildlife Conservation regulations.

Butterflies

The Ghana Wildlife Society (2007) recorded 100 species of butterflies outside of forest reserves in areas proposed for mining. Because of their mobility, butterflies are found within and outside of forest habitats. Human activities such as farming have negatively affected the diversity and abundance of butterfly species. No species were identified that are of conservation concern based on IUCN or CITES.

3.1.4 WETLANDS

The government of Ghana has developed a National Wetlands Conservation Strategy to identify and protect wetlands with significant ecological functions and values (Ghana Ministry of Lands, Forestry, and Mines 1999). The National Wetlands Conservation Strategy identifies wetlands as a range of habitats that have common features, the most important of which is continuous, seasonal or periodic water or saturated soils. Wetlands include areas of marsh, fen, peat or water, whether natural or artificial or flowing, fresh, brackish or salty. The National Wetlands Conservation Strategy discourages the following activities in wetlands with significant ecological functions and values:

- Physical draining of wetland water,
- Draining streams and water courses feeding wetlands,
- Human settlements and related infrastructural developments in wetlands,
- Disposal of solid waste and effluent in wetlands and
- Mining in wetlands.

The government of Ghana has not taken specific measures to identify and conserve wetlands in the Study Area.

Studies conducted in the Study Area found wetlands associated with the Pra and Mamang rivers, seasonal drainages and springs. These wetlands provide benefits to wildlife as a source of drinking water and breeding habitat. Human use of wetlands in the Study Area includes water for drinking and crop irrigation. Many wetlands that are inundated during the wet season are used as farm land during the dry season.

3.1.5 AQUATIC RESOURCES

Two components of aquatic resources have been characterized in the Study Area – fish fauna and macroinvertebrates. Discussions regarding the occurrence, distribution and characteristics of these types of fauna are presented herein.

FISH

A comprehensive fish and aquatic resource study was completed in the Study Area in 2007 and 2008 by Dr. John Blay of the University of Cape Coast (Blay 2008a and 2008b, as reported in Geomatrix 2008c) that focused on updating studies completed previously by SGS (2004c). **Figure 3-3** shows sampling stations used in the Blay (2008a and 2008b) study. Collected data indicate Study Area streams and rivers support an abundant and

Figure 3-3

diverse fish fauna that appears to have adapted to the conditions and seasonal variation of the rivers and streams that are typical for this area (Blay 2008a and 2008b). Fish species identified during two survey events completed within the Pra and Mamang rivers by Blay (2008a and 2008b) are summarized in **Table 3-4.**

The highest diversity of fish species and largest catches occurred in the middle reaches of both rivers in the Study Area. During the dry season sampling event, smaller catches and lower diversity were measured at survey stations located in tributaries to these rivers. This phenomenon is believed to be indicative of movement of fish from these areas and into the main stem reaches during the low flow period. Fish appear to move from the Pra River and Mamang River into the tributary channels during the wet season for spawning, rearing and refuge during the high flows in the main river channels. The results of these studies suggest the Pra and Mamang rivers support relatively diverse and abundant fish populations.

Whole fish samples were collected from rivers and streams in the Study Area for analysis of metals. Levels of metals in fish above consumption guideline values can be a health concern for the people that eat the fish. Blay (2008a) collected 12 samples of fish from nine different sites; four on the Mamang River, three on the Pra River and one from the Abesu Stream. These samples were analyzed for arsenic, cadmium, chromium, copper, lead, zinc and mercury. **Table 3-5** summarizes the analytical results from this sampling effort. Analyses were completed for two different kinds of mercury: total mercury and the organic form of this metal, methyl mercury. Methyl mercury is considered the most dangerous because it is in a form that is readily available to biological systems. Mercury accumulates in animals through the food chain; therefore, higher level predators, such as tiger fish, tend to have higher concentrations of mercury in their systems. Humans, as the top predator, can also accumulate mercury from their food sources, like fish.

Studies conducted in the Pra River basin by Donkor et al. (2006) identified mercury as a contaminant of concern in local fish populations. Four of the 21 sample locations reported in the Donkor study were within or just downstream of sample sites used during the Blay (2008a) study. Donkor et al. (2006) sampled for mercury in what they referred to as "environmental compartments", which included efforts to concurrently sample local soils, water, sediment, fish tissue and human hair from the local population. Relatively high mercury concentrations were identified in all "environmental compartments" studied; the authors attributed the high mercury levels to present and past "artisanal gold mining" (Donkor et al. 2006).

Donkor et al. (2006) tested for mercury in fish tissue obtained from 12 fish (combined into four composite samples), all smoked and dried, obtained in local markets that were locally caught from the Pra River basin. The samples analyzed included four different fish families. Three of the four families (two cat fish or mud fish families and the African pike) had tissue mercury levels that exceeded the World Health Organisation safe consumption guideline of 0.5 milligram per kilogram (mg/kg). The Blay (2008a) whole fish samples showed mercury concentrations (0.044 to 0.378 mg/kg; **Table 3-5**) below the World Health Organisation guideline, but 11 of the 12 samples exceeded a United States-based subsistence fish tissue consumption guideline of 0.049 mg/kg (Oregon Department of Environmental Quality, 2007).

TABLE 3-4
Fish Species Distribution in the Akyem Study Area
During Wet and Dry Seasons

Species		Pra River Abodum	Pra River Ntronang	Pra River Kotokuom	Pra River Ofoase Praso	Mamang River Labrikrom	Mamang River Mamanso	Mamang River Nkwanten	Mamang River Kotokuom	Akresu Stream Abodum	Afosu Stream Afosu	Abesu Stream Old Abirem
Alestidae - Tiger Fish and African Tetras												
Brycinus	*leuciscus*	X	X	X	X	X	X	X	X			X
Brycinus	*longipinnis*						X					
Micralestes	*occidentalis*	X	X	X	X	X	X	X	X			X
Brycinus	*imberi*		X			X	X					X
Brycinus	*macrolepidototus*		X									
Brycinus	*nurse*	X	X	X	X			X	X			X
Hydrocynus	*forskalii*			X	X							
Aplocheilidae - Kilifishes												
Epiplatys	*dageti*										X	
Poeciliidae - Lamp eyes												
Rhexipanchax	*schioetzi*		X	X		X	X					
Claroteidae												
Chrysichthys	*nigrodigitatus*		X		X							
Mochokidae - Upside-down catfishes												
Synodontus	*velifer*								X			
Schilbeidae - Glass catfishes												
Schilbe	*micropogon*											X
Schilbe	*mandibularis*			X	X							
Channidae - Snakehead												
Parachanna	*obsucra*		X									

TABLE 3-4 (continued)
Fish Species Distribution in the Akyem Study Area
During Wet and Dry Seasons

Species		Pra River Abodum	Pra River Ntronang	Pra River Kotokuom	Pra River Ofoase Praso	Mamang River Labrikrom	Mamang River Mamanso	Mamang River Nkwanten	Mamang River Kotokuom	Akresu Stream Abodum	Afosu Stream Afosu	Abesu Stream Old Abirem
Cichlid - Chiclids												
Tilapia	*zillii*	X		X		X	X	X	X	X	X	X
Chromidotilapia	*guntheri*	X	X	X			X	X				
Sarotherodon	*galilaeus*			X	X							
Hemichromis	*fasciatus*	X		X	X		X	X	X	X	X	X
Tilapia	*guineensis*							X				
Tilapia	*busumana*					X		X				
Distichodontidae												
Nannocharax	*fasciatus*		X									
Neolebias	*unifasciatus*					X						
Clariidae - African catfihes												
Heterobranchus	*longifilis*	X			X		X	X			X	X
Clarias	*gariepinus*						X	X	X			X
Clarias	*laeviceps*	X										X
Clupeidae - Freshwater Herring												
Pellonula	*leonensis*		X									
Cyprinidae - Minnows and Carps												
Barbus	*trispilos*	X	X	X	X	X	X	X	X	X	X	X
Barbus	*macrops*					X						
Barbus	*punctitaeniatus*	X	X		X	X	X	X	X	X	X	X
Labeo	*parvus*		X		X	X	X				X	X
Raiamas	*senegalensis*				X							
Barbus	*subinensis*	X	X			X	X		X		X	X

TABLE 3-4 (continued)
Fish Species Distribution in the Akyem Study Area
During Wet and Dry Seasons

Species		Pra River Abodum	Pra River Ntronang	Pra River Kotokuom	Pra River Ofoase Praso	Mamang River Labrikrom	Mamang River Mamanso	Mamang River Nkwanten	Mamang River Kotokuom	Akresu Stream Abodum	Afosu Stream Afosu	Abesu Stream Old Abirem
Hepsetidae - African Pike												
Hepsetus	*odoe*	X		X	X		X	X	X			X
Mastacembelidae - Spiny eels												
Mastacembelus	*nigromarginatus*			X				X				

TABLE 3-5
Concentrations of Metals in Whole Fish Samples Collected on the Pra and Mamang River Basins and Tributaries during the Wet Season (October-November 2007)
(micrograms per kilogram wet weight)
Akyem Gold Mining Project

Station	Species	Wet Wt. (grams)	Arsenic[1]	Cadmium[2]	Chromium	Copper	Lead[3]	Total Mercury[4]	Methyl Mercury[4]	Zinc
Abesu	*Hepsetus odoe*	84.1	<5	<10	<190	530	<15	152	122	9,580
GRSW-16b	*Labeo parvus* & *Barbus trispilos*	43.7	84	23	580	1,550	75	124	106	30,800
GRSW-21c	*Brycinus nurse*	160	<39	57	<200	430	50	67.2	44.4	11,400
GRSW-21c	*H. odoe*	630	<39	<10	<190	560	<15	262	253	6,770
GRSW-23	*B. trispilos*	43.7	<37	11	<210	740	73	171	170	38,700
GRSW-24	*Clarias gariepinus*	154.5	<36	10	<190	810	25	118	108	14,300
GRSW-25	*H. odoe*	210	<38	<10	<210	410	<15	172	176	7,720
GRSW-26	*Hydrocinus forskalii*	198	<37	11	<190	360	<15	378	351	6,670
GRSW-26	*Hemichromis fasciatus*	67	<38	<10	<190	580	<15	172	194	17,800
GRSW-27	*L. parvus*	255	102	42	340	830	62	53.5	49.7	26,100
GRSW-27	*H. odoe*	560	<36	<10	<210	440	<15	321	319	4,930
GRSW-28	Multiple species composite	62.5	<37	10	200	800	24	106	105	27,000

Table 3-5 (continued)

[1] Acceptable Tissue Level (ATL) for chemical in fish/shellfish consumed by humans:
Carcinogenic: Recreational/General – 6.2 µg/kg wet wt; Subsistence/Tribal – 0.76 µg/kg wet wt
Non-carcinogenic: Recreational/General – 1,200 µg/kg wet wt; Subsistence/Tribal – 150 µg/kg wet wt

[2] ATL for chemical in fish/shellfish consumed by humans:
Carcinogenic: Recreational/General – not applicable
Non-carcinogenic: Recreational/General – 4,000 µg/kg wet wt; Subsistence/Tribal – 490 µg/kg wet wt

[3] ATL for chemical in fish/shellfish consumed by humans:
Carcinogenic: Recreational/General – not applicable
Non-carcinogenic: Recreational/General – 500 µg/kg wet wt; Subsistence/Tribal – 500 µg/kg wet wt

[4] ATL for chemical in fish/shellfish consumed by humans:
Carcinogenic: Recreational/General – not applicable
Non-carcinogenic: Recreational/General – 400 µg/kg wet wt; Subsistence/Tribal – 49 µg/kg wet wt

References

Blay, (2008a); Oregon Department of Environmental Quality, (2007).

The precise source of the mercury measured in fish samples is unknown. Detectable concentrations of mercury were measured in a few surface water and stream sediment samples collected in the area; the highest concentrations appeared to occur in samples obtained from tributary channels to the Pra and Mamang Rivers. Surface soil and groundwater samples collected in the vicinity of these primary water courses did not exhibit mercury concentrations of significance.

MACROINVERTEBRATES

Findings from the macroinvertebrate fauna survey conducted by Blay (2008a and 2008b as reported in Geomatrix 2008c) indicated the Pra and Mamang river drainages lacked many of the species that are indicators of clean water. Those species identified are primarily indicators of enriched water or water impacted by microbiological organisms, which was evident in the Study Area. Benthic invertebrates in the Study Area consist mainly of nymphs and larvae of midges and other insects, round worms (nematodes) and snails. **Table 3-6** summarizes the species identified during the 2007 and 2008 surveys during the rainy and dry seasons, respectively.

The variation in diversity between the wet and dry seasons is exemplified by sampling at Mamanso on the Mamang River. During the dry season, this river reach had the lowest species diversity (8 species) but during the wet season, the same sampling station had the highest species diversity (32 species). This seasonal variation indicates that care must be used when utilizing species diversity to interpret water quality results.

Additional discussions on the baseline fish and macroinvertebrates present within the Study Area, including a species list, is included n **Annex C-2**.

TABLE 3-6
Comparison of Benthic Invertebrate Occurrences in Pra River Basin
During the Wet (November 2007) and Dry (January 2008) Seasons
Pra River Aquatic Studies at Akyem Gold Mining Project

	Pra River Basin Stations*																			
ORDER/Family/Species	**1W**	**1D**	**2W**	**2D**	**3W**	**3D**	**4W**	**4D**	**5W**	**5D**	**6W**	**6D[a]**	**7W**	**7D**	**8W**	**8D**	**9W**	**9D**	**10W**	**10D**	**11W**	**11D**
DIPTERA																						
Chironomidae																						
Chironomus sp.	◆	◆		◆																	◆	
Cryptochironomus sp.	◆	◆	◆	◆	◆	◆	◆	◆		◆	◆		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
Stictochironomus sp.		◆		◆	◆	◆		◆	◆	◆						◆	◆	◆	◆	◆	◆	◆
Clinotanypus claripennis	◆	◆	◆	◆		◆		◆		◆				◆		◆				◆		
Polypedilum sp.					◆	◆				◆				◆			◆	◆			◆	
Ablabesmyia dusoleili		◆	◆		◆	◆					◆				◆	◆	◆	◆	◆			
Procladius sp.		◆		◆		◆										◆						
Stenochironomus sp.						◆	◆			◆						◆		◆				
Tanytarsus sp.					◆																◆	
Nilodorum sp.		◆																				
Nanocladius sp.																				◆		
Unidentified sp.		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆		◆				◆	◆	◆	◆	◆	◆
Ceratopogonidae																						
Ceratopogon sp.		◆		◆		◆								◆						◆	◆	
Tipulidae																						
Eriocera sp.		◆																				
Unidentified sp.																◆						
Simulidae																						
Simulium sp.																						◆
EPHEMEROPTERA																						
Caenidae																						
Caenomedea sp.		◆	◆		◆	◆	◆	◆	◆	◆	◆		◆	◆		◆	◆	◆	◆	◆	◆	◆
Baetidae																						
Cloeon sp.				◆																		
Centroptilum sp.		◆	◆	◆	◆	◆			◆		◆				◆	◆	◆	◆	◆		◆	◆
Leptophlebiidae																						
Thraulus sp.						◆				◆						◆					◆	
Chorotezpes sp.									◆								◆				◆	
Tricorithidae																						
Dicercomyzon sp.																		◆				

TABLE 3-6 (continued)
Comparison of Benthic Invertebrate Occurrences in Pra River Basin
During the Wet (November 2007) and Dry (January 2008) Seasons
Pra River Aquatic Studies at Akyem Gold Mining Project

	Pra River Basin Stations*																	
ORDER/Family/Species	**1W**	**1D**	**2W**	**2D**	**3W**	**3D**	**4W**	**4D**	**5W**	**5D**	**6W**	**6D[a]**	**7W**	**7D**	**8W**	**8D**	**9W**	**9D**	**10W**	**10D**	**11W**	**11D**
Heptageneidae																						
Afronurus sp.																					◆	
Notonurus sp.					◆																	
Polymitarcyidae																						
Povilla sp.																◆						
TRICHOPTERA																						
Ecnomidae																						
Ecnomus sp.			◆			◆					◆		◆							◆		
Hydropsychidae																						
Cheumatopsyche falcifera											◆											
Cheumatopsyche sp.																						◆
Polymorphanisus sp.																						
Unidentified species							◆															
Philopotamidae																						
Chimarra petri						◆				◆				◆								
Unidentified sp.							◆										◆					
Leptoceridae																						
Leptoceris sp.							◆															
Oecetis sp.																	◆					
Unidentified Family				◆		◆								◆				◆		◆		◆
PLECOPTERA																						
Unidentified Family																		◆				
ODONATA																						
Corduliidae																						
Unidentified sp.								◆					◆									
Libellulidae																						
Unidentified sp.				◆																		◆
Gomphidae																						
Phyllogomphus sp.																	◆					
COLEOPTERA																						
Elmidae																						
Unidentified sp.						◆	◆			◆								◆	◆		◆	◆

TABLE 3-6 (continued)
Comparison of Benthic Invertebrate Occurrences in Pra River Basin
During the Wet (November 2007) and Dry (January 2008) Seasons
Pra River Aquatic Studies at Akyem Gold Mining Project

	Pra River Basin Stations*																			
ORDER/Family/Species	**1W**	**1D**	**2W**	**2D**	**3W**	**3D**	**4W**	**4D**	**5W**	**5D**	**6W**	**6D[a]**	**7W**	**7D**	**8W**	**8D**	**9W**	**9D**	**10W**	**10D**	**11W**	**11D**
COLLEMBOLA																						
Isotomidae																						
Unidentified sp.				◆		◆			◆											◆		
NEMATODA																						
Unidentified sp.	◆		◆		◆	◆	◆	◆	◆	◆			◆	◆	◆	◆	◆		◆		◆	
OLIGOCHAETA																						
Unidentified sp.	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
HIRUDINEA																						
Unidentified sp.	◆										◆											
GASTROPODA																						
Thiaridae																						
Melania tuberculata								◆								◆					◆	◆
Lymnaidae																						
Ceratophalus sp.																◆						
Bulinidae																						
Bulinus sp.	◆	◆		◆																		
Bulinus jousseaumei											◆											
Unidentified species		◆			◆	◆																
BIVALVIA																						
Unionidae																						
Coelatura sp.							◆							◆		◆						
CRUSTACEA																						
Copepoda																						
Unidentified sp.																						
Cyclops sp.				◆																		
Shrimp (unidentified)						◆										◆						

* Corresponding Surface Water Sampling Stations: 1. Abesu 2. GRSW-4 3. GRSW-16B 4. GRSW-21C 5. GRSW-22 6. GRSW-23 (a: not sampled during dry season) 7. GRSW-24 8. GRSW-25 9. GRSW-26 10. GRSW-27 11. GRSW-28

Explanation: W: Wet Season
D: Dry Season

3.2 PHYSICAL ENVIRONMENT

The Study Area for the Project is characterized by relatively steep hills and undulating grasslands. Small seasonal streams drain to the Pra and Mamang rivers, the primary surface water features in the area. Elevations in the Proposed Mining Area range from approximately 150 to nearly 300 metres above mean sea level. Descriptions of the air, geology, water and soil resources within the Study Area are presented in the following sections.

3.2.1 CLIMATE AND AIR QUALITY

The climate and ambient air quality in the Study Area is characterized using general climate information and gaseous and particulate monitoring data, respectively. The primary sources of emissions are from crop or bush burning on farms and local traffic along unsealed roads. The Study Area is influenced by the northerly dust-laden "Harmattan" winds, emanating from the Sahara Desert; these winds typically occur during the dry season from December to February.

Discussion in this section is focused on describing the climate and air quality in the Study Area. Meteorological and air quality data to support these descriptions were reported in a prior EIS for the Project or were gathered during Company-sponsored baseline studies of the area.

CLIMATE

The Study Area is located within the wet semi-equatorial climatic zone of Ghana which is characterized by an annual double maxima rainfall pattern; wet seasons usually occur from March to July and September to mid-November. The climate type is determined by movement of the Inter-Tropical Convergence Zone, which oscillates annually about the equator attracting air masses from the north and south. Southern air masses, emanating from the anticyclone of St. Helena in the South Atlantic, bring relatively cool, moist weather. Northern air masses, locally called "Harmattan," come from the sub-tropical Azores anticyclone and its extension over the Sahara desert. These air masses bring hot, dry weather from December through February.

Historical average annual precipitation and monthly mean temperature data for towns and villages in the area are shown in **Table 3-7**. Based on these data, rainfall in the area has an annual double peak regime, the first peak occurring around June during the major rainy season which typically extends from late March to the end of July. During this period, about 55 to 60 percent of total annual rainfall is recorded. The second peak occurs in October during the minor rainy season that usually extends from late-September to mid-November. Minimal rainfall is experienced in the area from December through February.

Mean monthly temperatures in the Study Area **(Table 3-8)** are relatively consistent, varying from about 25 to 27 degrees Celsius (˚C); the lowest recorded temperature during the period of record (1970 to 2004) was 19.4˚C and the maximum recorded temperature was 35.4˚C.

TABLE 3-7
Mean Temperature and Annual Precipitation
for Communities in the Vicinity of Akyem Gold Mining Project Study Area

Location/ Period of Record	Afosu (1997-2004)		Kade (1970-2002)		Nkawkaw (1970-2002)		Konongo (1970-2002)		Akim-Oda (1961-2000)	
Month	**Precip. (mm)**	**Temp. (°C)**	**Precip. (mm)**	**Temp. (°C)**	**Precip. (mm)**	**Temp. (°C)**	**Precip. (mm)**	**Temp. (°C)**	**Precip. (mm)**	**Temp. (°C)***
January	13.7	27.0	15.2	26.8	11.0	26.4	11.1	25.3	20.7	--
February	41.5	27.9	55.6	28.2	48.8	28.1	56.2	27.1	56.1	--
March	112.2	28.3	159.9	28.3	106.1	28.0	126.3	27.4	131.1	--
April	131.4	27.7	174.5	28.0	135.4	27.8	135.6	27.3	163.3	--
May	168.0	26.2	165.7	27.6	155.0	27.3	151.0	27.1	186.2	--
June	208.8	26.4	192.5	26.8	216.9	26.3	206.1	26.0	215.9	--
July	153.2	25.5	134.8	25.8	186.9	25.3	156.6	25.1	131.8	--
August	85.8	24.9	99.5	25.6	142.8	24.9	100.0	24.9	83.2	--
September	177.4	25.5	150.7	26.2	187.4	25.5	160.2	25.3	129.1	--
October	190.7	26.5	197.2	27.0	172.4	26.2	147.7	25.9	185.6	--
November	65.2	26.9	101.2	27.3	47.1	27.0	68.9	26.3	116.2	--
December	33.9	26.7	41.1	26.8	23.0	26.2	20.6	25.4	43.8	--
Total/Mean	**1380.1**	**26.7**	**1487.9**	**27.0**	**1432.8**	**26.1**	**1340.3**	**26.6**	**1463.6**	--

Source: SGS (2004d)
Precip. = Precipitation; Temp. = temperature; mm = millimetres; * temperatures unavailable for Akyem-Oda.

TABLE 3-8
Mean Monthly Temperature, Relative Humidity
and Total Precipitation (2007)
Akyem Gold Mining Project Study Area

Station	Weather Station		Evaporation Station	Rainfall Station
Month	**Temperature (°C)**	**Relative Humidity (%)**	**Evaporation (mm)**	**Precipitation (mm)**
January	25.2	59.3	6.41	25.0
February	27.3	72.9	121	4.50
March	27.4	73.3	122	72.8
April	26.6	78.7	160	120
May	26.3	80.7	79.8	95.8
June	25.1	84.3	205	148
July	24.5	84.7	216	235
August	24.2	85.8	93.0	123
September	24.7	85.3	358	378
October	24.6	84.8	245	171
November	25.4	83.3	92.3	82.0
December	25.7	80.4	23.6	13.5
Mean/Total	**25.6**	**79.5**	**1,721**	**1,467**

Source: Clear Creek Consultants (2008a).
mm = millimetres; °C = degrees Celsius; % = percent.

Temperature, relative humidity, evaporation and rainfall have been measured at a weather station installed within the Study Area during the summer of 2006. **Table 3-8** summarizes the climatic data collected from this site in 2007. These data largely confirm the seasonal patterns exhibited in the historical data collected in area communities and villages.

AIR QUALITY

Several environmental factors can influence air quality in the Study Area including mining, logging and agricultural practices. The impacts of these activities on air quality are generally localized and do not contribute substantially to regional degradation of air quality. Motor vehicles are the primary source of gaseous pollutants in the Study Area, but the generally low numbers of vehicles would indicate these are also a minor source of gaseous pollutants. During certain times of the year, crop field burning is a source of gaseous pollutants, although these activities typically occur for a short period of time.

Particulate pollutants are generally caused mainly by large dust sources in the Sahara Desert, particularly from December to February, when the "Harmattan" wind brings dust from the north. In addition to these natural sources of dust, vehicular traffic on unpaved roads also contributes particulate loading to the atmosphere.

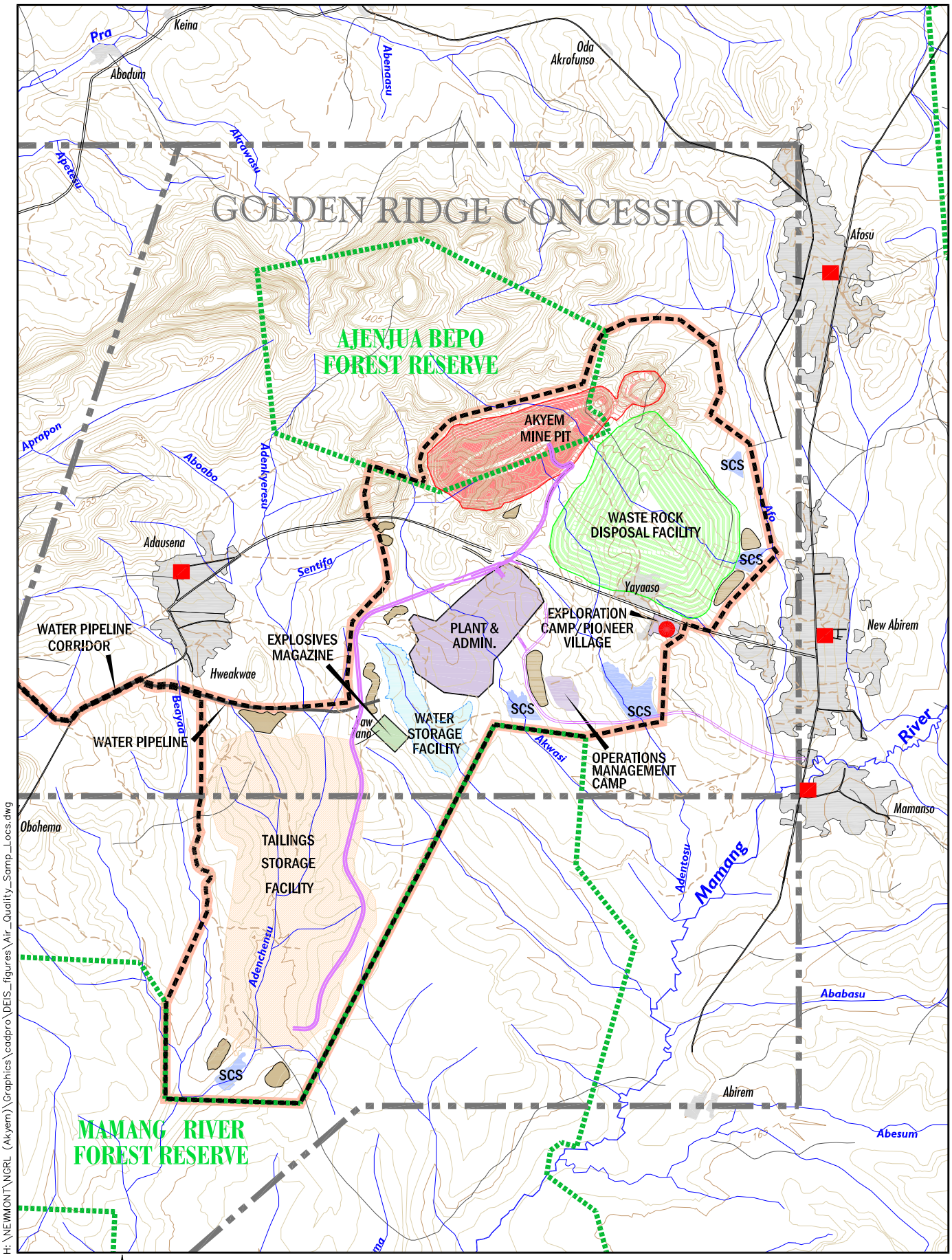
No historical ambient air quality data are available for the Study Area. The Company installed a PM_{10} air sampler device at the Exploration Camp in April 2007 to obtain baseline data. In addition to the primary air quality sampler, two smaller portable PM_{10} samplers were used to sample air in several villages within the Study Area (Afosu, Adausena, Mamanso and New Abirem) on a rotating basis, starting in September 2007. Locations of air sampling sites are shown on **Figure 3-4**. **Tables 3-9** and **3-10** summarize air quality data collected by the primary PM_{10} sampler, and the portable PM_{10} samplers, respectively.

TABLE 3-9
Primary Sampler PM_{10} Data
Particulate Concentration (µg/m³)
Akyem Exploration Camp (2007)

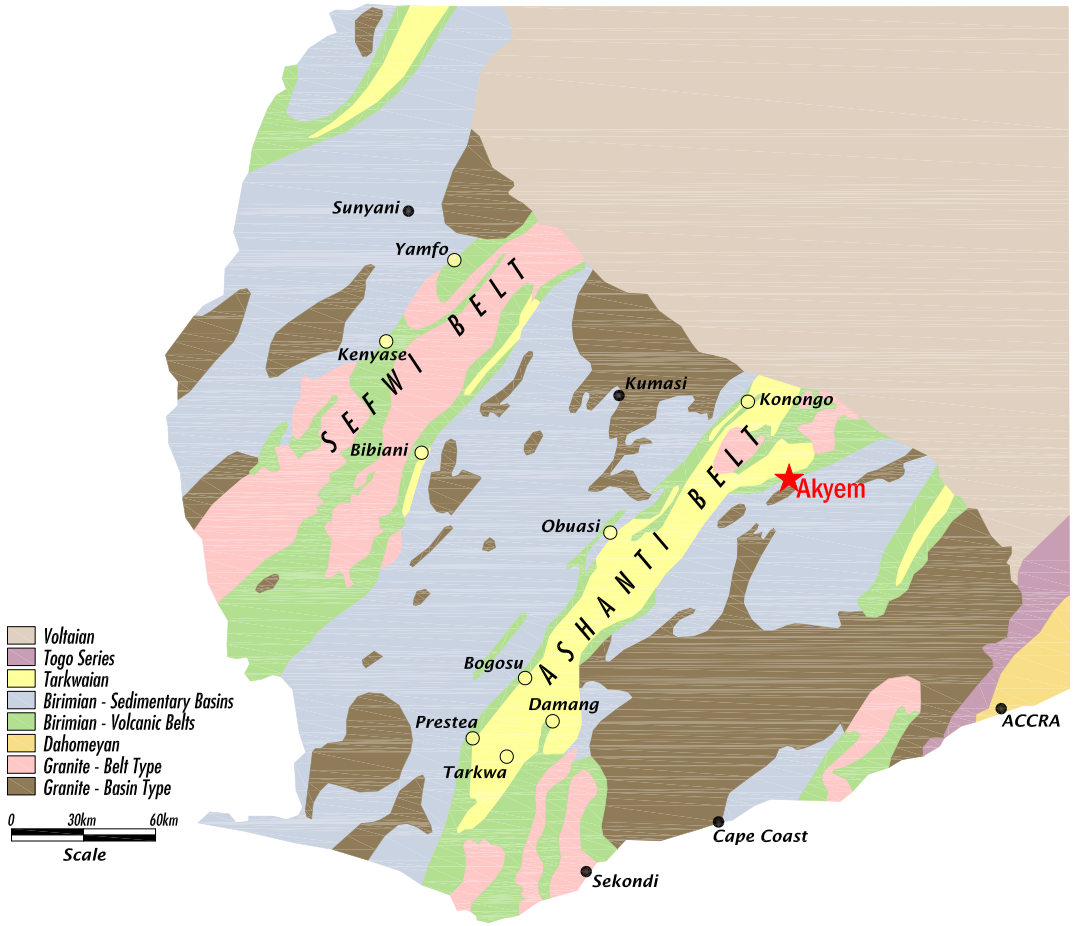
Month	No. of Samples	Average	Maximum	Minimum
April	2	23.00	26.29	19.72
May	5	30.42	44.05	21.38
June	6	15.80	24.67	5.32
July	6	16.17	22.13	0.79
August	5	18.85	25.67	12.44
September	5	11.65	14.89	10.23
October	5	13.01	16.47	10.19
November	1	15.52	15.52	15.52

µg/m³ = micrograms per cubic meter

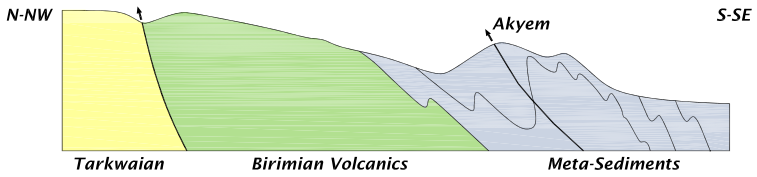
The data indicate air quality in the Study Area and surrounding communities is generally good. "Harmattan" wind conditions, which are reflected in the portable sampler data from December and January (**Table 3-10**), indicate air quality deteriorated during these months with particulate concentrations occurring at levels that exceeded European Union, World Health Organisation, and EPA standards.



Air Quality Sample Locations
Akyem Gold MIning Project
Eastern Region, Ghana
FIGURE 3-4



Southern Ghana Regional Geologic Map



Regional Geologic Cross-Section

1km

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Source: Knight Piesold (2004).

Regional Geology
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-5

TABLE 3-10
Portable Sampler PM_{10} Data
Particulate Concentration (µg/m³)
Akyem Gold Mining Project Study Area and Nearby Communities (2007-2008)

Month	Adausena	Afosu	Study Area	Mamanso	New Abirem
September 2007	23.90	37.92	16.30	25.94	19.71
October 2007	18.96	30.77	17.10	47.84	38.72
November 2007	32.35	39.31	73.13	50.28	43.78
December 2007	125.83	126.37	91.21	300.42	99.17
January 2008	408.30	475.90	203.18	301.11	170.99

Note: The Study Area concentration for December 2007 is the average of five samples and the Study Area concentration for January 2008 is the average of three samples. PM_{10} = particulate matter in 10 micron size fraction. µg/m³ = micrograms/cubic metre.

3.2.2 GEOLOGY AND MINERALS

The geology and mineral characteristics of the Study Area and, more particularly, within the Proposed Mining Area are discussed in this section. Particular emphasis is placed on describing the geology with respect to geochemical character. More detailed discussions of site geology and characteristics of mineralization, alteration and geochemistry are included in **Annex C-3.**

REGIONAL GEOLOGIC SETTING

Ghana is located largely within the Precambrian Guinea Shield of the West African Craton, which stabilized during the early Proterozoic Era (about 2000 million years ago). These early Proterozoic rocks comprise extensive northeast-trending belts of folded, metamorphosed volcanic and sedimentary rocks (i.e., Birimian and Tarkwaian units) (**Figure 3-5**). Intruded into the Birimian rocks are large masses of granitoid. Late Proterozoic to Paleozoic sedimentary rocks of the Voltaian System overlie these oldest Precambrian rocks and consist of sandstone, mudstone, conglomerate, limestone and tillite (Ghana Minerals Commission and Watts, Griffin, and McQuade, Inc. 1998).

The most striking feature of the geology of Ghana is the parallel alignment of narrow (15 to 40 kilometres wide), somewhat evenly spaced, northeasterly trending belts of folded Birimian metavolcanic rocks (**Figure 3-5**). Between these belts are broad (approximately 60 to 90 kilometre wide) sedimentary "basins" consisting predominantly of Birimian turbidity sedimentary rock sequences (Ghana Minerals Commission and Watts, Griffin, and McQuade, Inc. 1998; Ireland *et al.* 2001). During regional metamorphism, these sediments were changed to metasediments. **Annex C-3** includes more detailed descriptions of the various terrains that have developed in Ghana based on major rock types present in the area as well as gold mineralization in the region that includes the Study Area.

LOCAL GEOLOGIC SETTING

The Proposed Mining Area is located at the northern end and along the southeast margin of the Ashanti Belt (**Figure 3-5**). The Ashanti Belt has historically produced approximately 40 million ounces of gold and may have resources of a similar magnitude (Ghana Minerals Commission and Watts, Griffin, and McQuade, Inc. 1998). The east-northeast striking Akyem deposit is developed in Birimian rocks on the southern limb of a major regional fold structure called the Noyem Syncline and is intimately associated with a mylonitic shear zone (Feybesse 1999; Lescuyer 1999) that occurs near the contact of metavolcanic (i.e., mafic volcanic) and overlying metasedimentary (i.e., greywacke) units (**Figure 3-6**). The base of mineralization corresponds to a near-planar thrust zone dipping approximately 60 degrees to the south-southeast, generally parallel to the layering of the sequence (Ireland *et al.* 2001). The variably mineralized metasedimentary rocks are about 100 metres in true thickness.

The geologic section at the Akyem deposit is depicted graphically on **Figure 3-7** and shows rock units, the shear or thrust fault zone, ore zone, and proposed Akyem pit outline. Key geologic units in the hanging wall of the thrust fault include greywacke, a quartz-epiclastic unit, graphitic shear breccia and graphitic rubble. Mafic metavolcanics comprise the foot wall of the shear zone (**Figure 3-7**). Geologic units in the Proposed Mining Area are described in a stratigraphic section depicted in **Table 3-11**. Additional discussion on the geologic setting, gold mineralization and alteration characteristics of the local geologic environment is included in **Annex C-3.**

The geology and mineral characteristics of the Study Area and, more particularly, within the Proposed Mining Area are discussed in this section. Particular emphasis is placed on describing the geology with respect to the geochemical character of the various rock types. Detailed discussions of site geology and characteristics of mineralization, alteration and geochemistry are included in **Annex C-3.**

tBc
tP
tB
bvm
sv
s

TARKWAIAN CLASTIC SEDIMENTS

BIRIMIAN VOLCANICS AND VOLCANOSEDIMENTS

METASEDIMENTARY BASIN ROCKS

PRA RIVER

AJENJUA BEPO FOREST RESERVE

AURO RIVER FOREST RESERVE

MAMANG RIVER FOREST RESERVE

Generalized Cross Section

AKYEM PIT

WASTE ROCK DISPOSAL FACILITY

PROCESSING FACILITIES

WSF

OMC

TAILINGS STORAGE FACILITY

Ntronang

Adausena

Hweakwae

Obohema

Afosu

Afoso

Yayaaso

New Abirem

Mamanso

MAMANG RIVER

h:\NEWMONT\NGGL (Akyem)\Akyem Generalgis\Projects\Draft_EIS\Akyem_geology.mxd

N

0 Kilometres 2

Source Geologic Data: Newmont (2008).

- Proposed Mining Area
- Forest Reserve Boundaries
- Primary Roads
- Secondary Roads
- Villages

Geologic Symbols

- Structural Trend Lines
- Dolerite dyke, post-Birimian
- Fault
- Major thrust fault
- Fold axis, anticline; commonly sheared-out
- Fold axis, syncline; commonly sheared-in

Note: Generalized Geologic Cross Section presented on Figure 3-7.

Geologic Units

- tBc Banket Series: quartz pebble conglomerate, auriferous
- tP Tarkwa Phyllite: Chloritoid-chlorite-magnetite-carbonate phyllite
- tB Banket Series: Undifferentiated; quartzite, feldspathic quartzite, grit, conglomerate
- bvm Basalt, dolerite: Amphibolite; tholeiitic; interbedded mafic volcaniclastics
- sv Volcaniclastics and metasediments
- s Metasedimentary rocks, undifferentiated

Akyem Project Area Geology
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-6

Figure 3-7

TABLE 3-11
Stratigraphic Section for Akyem Gold Mining Project Gold Deposit

	Geologic Unit	Thickness	Description
	Red Lateritic Clay	1 to 5 metres	Red clay with rounded quartz fragments.
	Saprolite	10 to 50 metres	Tan to brown-ochre saprolite, predominantly lateritic clay and quartz fragments, with abrupt oxide-to-sulfide transitions as much as 25% weathered rock.
	Greywacke	NA	Fine-grained clastic metasedimentary unit; greywacke, argillite / black carbonaceous siltstone and feldspathic sandstone with small-scale asymmetric folds.
	Quartz Vein	≤ 1 to 8-10 metre thickness	White to gray quartz with minor rock wall fragments and late crosscutting dark gray quartz. Veins typically occur in greywacke and at Quartz-eye porphyry contact.
	Quartz Porphyry (Quartz-Epiclastic)	50 centimetres to 20 metres	Predominantly a gray-green-pink unit containing trace bluish-gray quartz phenocrysts in a mylonitized (sheared) matrix bound by an upper and lower sheared breccia zone.
	Mafic Metavolcanic	10 to 70 metres	Massive, sheared dark gray and green chlorite-carbonate rock containing zones of euhedral magnetite. Typically mineralized and in the hanging wall of major thrust/shear.
	2nd Metavolcanic	NA	Typically gray-green, chlorite-carbonate rock more massive and brittle that unit above, typically in footwall of major thrust fault /shear
	Graphitic Mylonite	NA	Predominantly lens of fragmented rock in a matrix of plastically sheared graphitic material with mylonitic foliation defined by graphite.
	Graphitic Rubble	NA	Graphitic mylonite cut by brittle shears, rubbly, fragments covered on all sides by striated graphitic slicks.

Source: Lycopodium Pty Limited (2004).
NA = not available.

GEOCHEMICAL CHARACTERIZATION OF ROCK

The Company conducted a series of tests to evaluate the rock to be mined and processed in conjunction with the Project to provide data to gain an understanding of how the rocks would interact with the environment following removal of rock from the mine pit. Test data are used in designing a mine plan that minimizes impacts to the environment. During mining, rock is broken up and brought to the land surface for disposal (waste rock) or processing to remove the gold (ore). Ore processing includes crushing and grinding steps followed by extraction of the gold in the mill. The milling process generates waste (tailings) comprised of sand-size and smaller particles that can be reactive when subjected to weathering (contact with oxygen and water, such as rain, surface water, and mine process water). Non-mineral bearing materials excavated from the open pit will be stored in a waste rock disposal facility where the rock can also be subjected to oxygen and water that promote weathering and potential release of chemical constituents.

Rocks brought to the surface during mining are made up of different minerals (e.g., calcite = calcium carbonate, pyrite = iron sulphide, quartz = silicon dioxide) that have distinct properties that control how they will react when exposed to air or water. Minerals that dissolve in water (calcite) could release their components (calcium, carbon, and oxygen) to the water. Some minerals, when placed in contact with water, would not dissolve or may release very small amounts of the mineral components; other minerals are more easily dissolved or weathered.

Rocks associated with mineralised areas typically have a greater percentage of trace metals compared to rocks and soil in most other locations. Trace metals can be harmful if exposed to humans, fish, wildlife or vegetation, and if present at concentrations above certain regulatory standards or guidelines. The primary concern is the release of trace metals (e.g., arsenic, antimony, cadmium) to the environment at concentrations that exceed standards from two sources or pathways, including: (1) water running off the surface or emerging from the base of the waste rock disposal facilities and the Tailings Storage Facility; and 2) water that would collect in the mine pit after dewatering ceases.

Approximately 467 exploration boreholes were drilled in and adjacent to the mine pit, including a subset of borings that were advanced to depths that exceeded the projected pit bottom. Using these cores, Company geologists described the lithology, alteration and mineralogy of the rock package. This information provided the basis for the Company to select 207 samples obtained from 11 boreholes situated on representative cross sections through the mine pit (e.g., ore zone, waste rock zone) to conduct Phase I geochemical tests, including:

- Mineralogy and whole-rock chemistry: using semi-quantitative x-ray diffraction and x-ray fluorescence and
- Acid-base accounting (ABA) testing: parameters measured include acid neutralization potential (ANP), acid generation potential (AGP) and net carbonate value (NCV).

The Phase I data set provided a comprehensive understanding of the ore and waste rock geochemical characteristics associated with the proposed mine pit.

A second phase of geomchemical testing was conducted using 16 samples composited from core samples used to conduct Phase I tests that represented major lithologies, alterations

and ranges in NCV values. The Phose II testing was conducted to obtain data regarding the characteristics of water that would come in contact with the various rock types present in the pit. In addition to mineralogy, whole-rock chemistry and ABA, these tests included:

- Synthetic Precipitation Leaching Procedure (SPLP),
- Biological Acid Production Potential (BAPP) and
- Peroxide Acid Generation analyses.

A detailed discussion of the results of these tests is included in **Annex C-3**. Results of these tests indicate that, based on the rock core samples tested, rock to be mined has an overall net neutralizing potential and that sufficient neutralization capacity exists in the rock prevent acid generation in the waste rock facilities, Tailings Storage Facility and mine pit area (pit lake). Geochemical testing indicates the potential for certain trace metals (including aluminium, antimony and arsenic) to be released at relatively low concentrations from various rock types (**Annex C-3**).

The Company is performing additional geochemical testing (using kinetic tests) to further validate the test results to date and to better characterize resulting long-term water quality from contact with these various rock types. These additional tests will include selected Phase II tests (described above) plus column tests, designed to simulate various lithologies. Data resulting from the kinetic tests will be used, in conjunction with static test results, to conduct more sophisticated geochemical modelling directed at predicting the quality of water in the mine pit lake, following cessation of mining. These ongoing tests should also provide information addressing the potential for release of low level trace metals into the natural environment over time from waste rock disposal areas or from tailings stored in the Tailings Storage Facility. Based on these results, which are expected in late 2008 or early 2009, appropriate changes in the mine plan design would be made, as necessary.

As a means of comparison, the Company encountered a similar suite of trace metals in rock tested at other nearby mining operations. Kinetic testing results were input into a geochemical equilibrium model and predicted overall surface water quality would meet Ghana drinking water standards. Some trace metals, including antimony and manganese, and a sulphate anion (one pit only) may be present at concentrations slightly above Ghanaian drinking water standards in mine pit water (Geomatrix 2007a and 2007b). All other constituents were predicted to be present at concentrations below Ghanaian drinking water standards. Additional geochemical testing is currently ongoing to determine if iron complexing in the post-mine pit lake would occur under actual conditions, which would serve to further reduce the low levels of antimony, manganese and sulphate. Given the similarity in rock assemblages between the Akyem site and other nearby mine sites, it is expected that kinetic testing of rocks associated with the Akyem Gold Mining Project, combined with geochemical modelling, would yield similar results and these conclusions would be verified upon completion of kinetic testing.

3.2.3 WATER RESOURCES

The physical and chemical characteristics of water resources in the Study Area, including surface water and groundwater, are discussed in this section. More detailed discussions of site water resources are included in **Annex C-4.**

SURFACE WATER

The Study Area is located in the Pra River basin which flows south to the Gulf of Guinea (Atlantic Ocean) (**Figure 3-8**). The Pra River is the second largest river in Ghana with a total drainage area of 23,170 square kilometres. All of the proposed mine facilities (with the exception of the Pra River pumping station and a portion of the water pipeline) would be located in the Mamang River drainage (**Figure 3-9**), which joins the Pra River near the community of Kotokuom southwest of the Study Area. Areas to the north and west of the proposed mine facilities drain directly to the Pra River (**Figure 3-9**).

All surface water monitoring stations established for the Study Area are listed in **Table 3-12** and are shown on **Figure 3-9**. A total of four surface water monitoring stations are located on the Pra River, and two stations are located on tributary streams to the Pra River. Six surface water monitoring stations are located on the Mamang River, and 16 stations are located on tributary streams to the Mamang River. Monitoring at most stations began in 2001; however, several stations were added in 2007.

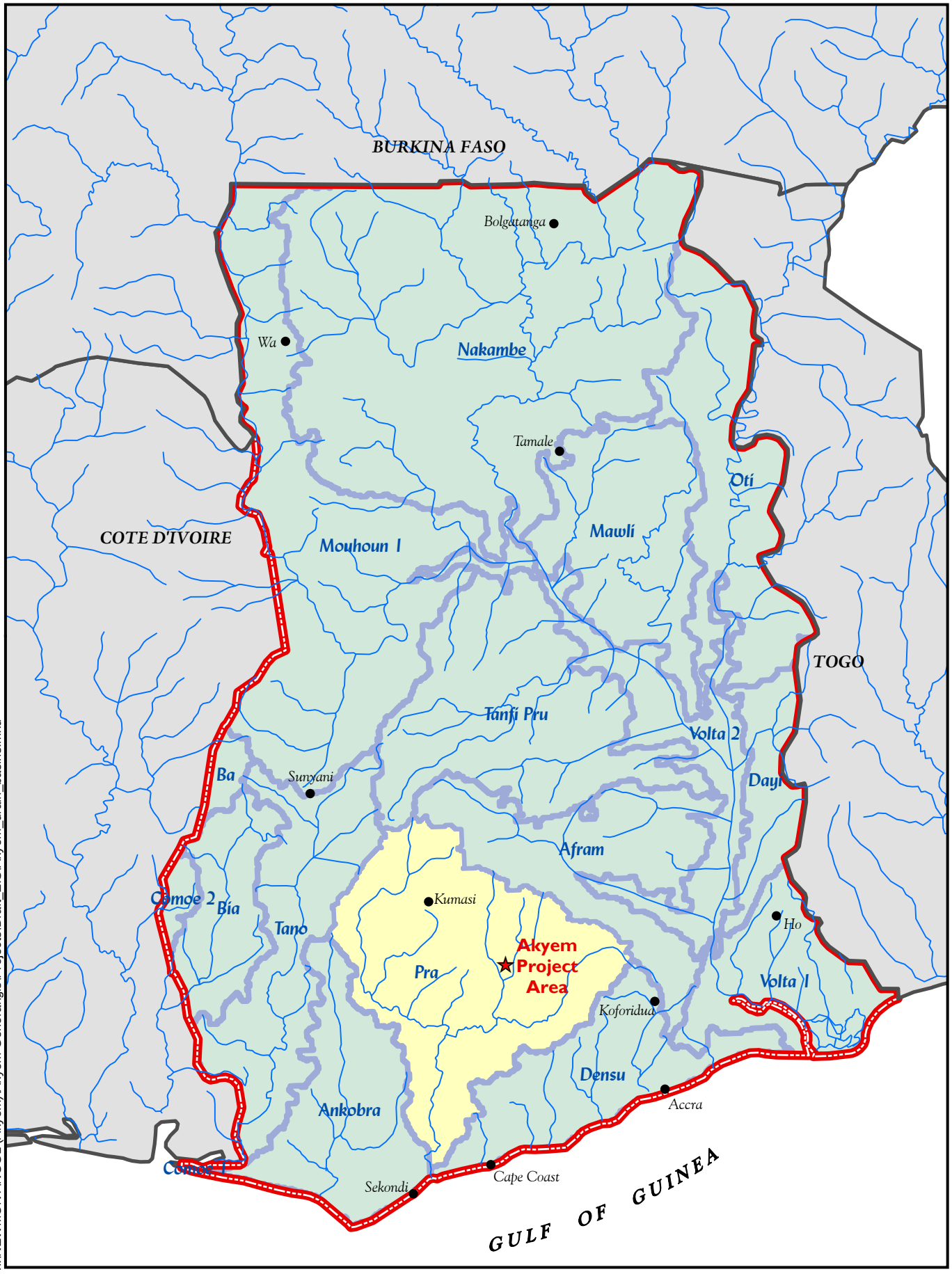
Surface Water Flow

Streams and rivers in the Study Area generally flow during the rainy season (May to November), with reduced or no flow occurring during the dry season (December to April). Lower reaches of the Pra River generally flow year-round (perennial); whereas, the upper Pra River, all of the Mamang River, and tributary streams flow seasonally during rainy periods. During dry periods, portions of channels that become dry often contain shallow pools of water.

The Pra River meanders in a well-defined channel (20 to 50 metres wide, and 3 to 5 metres deep) protected by a canopy of tall trees. Records of flow in the Pra River for the period of 1960-78 and 1991-99 are available for a gauging station located at the Ofoase-Praso Bridge (SW-27), 6 kilometres downstream of the Pra/Mamang river confluence. The Pra River watershed at this location covers an area of approximately 2,045 square kilometres.

Hydrographs of flow for the Pra River and Mamang River are included in **Annex C-4**. Mean annual discharge for the Pra River at the downstream end of the Study Area at the confluence of the Mamang River (SW-27 at Ofoase-Praso; 2,045 square kilometres) is 12 to 16 cubic metres per second (m^3/sec), with mean daily flows ranging from less than 2 m^3/sec during the dry season, to over 80 m^3/sec during the wet season. Mean annual discharge for the Pra River at the upstream side of the Study Area (SW-21 at Prasokuma; 875 square kilometres) is approximately 5.4 m^3/sec, with peak flows of up to 60 m^3/sec,, measured in September 2007 (Clear Creek Consultants 2008b). Stream flows measured in the Pra River where water will be abstracted to support the mine, is expected to be similar to flows measures at both the upstream (SW-21) and downstream (SW-22) stations.

The Mamang River watershed covers an area of approximately 475 square kilometres. Mean annual discharge calculated for the Mamang River at its mouth at SW-25 is approximately 2.9 m^3/sec. Peak flow measured in September 2007 at station SW-24 (drainage area = 384 square kilometres) is 68 m^3/sec (Clear Creek Consultants 2008b).



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0 Kilometres 100

Major River Basins of Ghana
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-8

Figure 3-9

TABLE 3-12
Surface Water Monitoring Stations in Akyem Study Area

Monitoring Station	Location
Pra River Drainage	
SW-21	Pra River upstream of Study Area near Prasokuma
SW-22	Pra River west of Study Area near Teshie-Praso and proposed water supply diversion
SW-26	Pra River above confluence with Mamang River near Kotokuom
SW-27	Pra River below confluence with Mamang River at Ofoase-Praso Bridge
SW-23	Akrawasu stream at mouth near Abodom and confluence with Pra River
SW-15	Aprapon stream near Ntronang
Mamang River Drainage	
SW-1	Ninki stream upstream of Afosu stream (new station in 2007)
SW-2/2A	Afosu stream below Ninki (SW-2A is upstream of former SW-2 station)
SW-3	Afosu stream above Yaayaaso (moved downstream)
SW-4	Afosu stream above Abirem-Yaayaaso road (moved upstream)
SW-5	Yaayaaso stream upstream of Yaayaaso village
SW-6	Adentosu stream west of Yaayaaso village
SW-7	Akwasi stream below proposed plant site
SW-8	Sentifa stream above confluence with Adenkyerensu stream
SW-9	Adenkyerensu stream above confluence with Sentifa stream
SW-10	Aboabo stream above confluence with Adenkyerensu stream
SW-18	Beayaa stream at Hweakwae village
SW-16/-16A	Mamang River near Labikrom village (SW-16A is upstream of former SW-16 station)
SW-17	Afosu stream upstream of Mamang confluence (new station in 2007)
SW-28	Mamang River at Mamanso village
SW-19	Adentosu-Akwasi stream above Mamang confluence (new station in 2007)
SW-29	Mamang River downstream of Akwasi stream
SW-20	Un-named tributary downstream of proposed plant site (new station in 2007)
SW-31	Mamang River downstream of East Tributaries (new station in 2007)
SW-24	Mamang River near Nkwanten-Kyia Bridge
SW-25	Mamang River above confluence with Pra River near Kotokuom
SW-30/-3A	Adenkyerensu stream above proposed TSF (SW-30A moved upstream of former SW-30)
SW-11	Adenkyerensu stream below proposed TSF (new station in 2007)

Note: See **Figure 3-9** for station locations. TSF = Tailings Storage Facility.

In April-May 2007, continuous recording stream gauging stations were installed on the Pra River by Clear Creek Consultants (2008b) at SW-21 (PRA-1, upstream) and SW-27 (PRA-2, downstream); and on the Mamang River at SW-28 (MAM-1, upstream) and SW-24 (MAM-2, downstream). Hydrographs for these four stations showing flow measured in 2007, including some individual measurements in 2004, are in **Annex C-4.**

Streams draining the Study Area that are tributary to the Pra and Mamang Rivers (including those emanating from the Ajenjua Bepo Forest Reserve) are ephemeral, flowing only during the wet seasons. Principal tributary streams in the area include the Afosu, Adentosu, Akwasi, and Adenkyerensu. Instantaneous flow measurements for tributary streams by Clear Creek Consultants (2008b) in July and October 2007 ranged from 0 to 0.5 m^3/sec.

Surface Water Quality

The surface water quality monitoring programme started in 2001 and consists of collection of water samples for analysis of chemical constituents. Sample locations have been chosen to characterize water quality in the region and to focus on locations where impacts could occur from the proposed Akyem Gold Mining Project. The most recent sampling in 2007 included 24 stations from which samples were collected in July and October.

Results of surface water analyses (SGS 2004g; Clear Creek Consultants 2008b) are summarized in **Annex C-4**. Water quality standards or guidelines for the parameters analyzed are presented in **Annex C-4**. Statistical summaries of all surface water quality data are grouped into the following categories: Pra River, Pra River tributaries, Mamang River, Mamang River tributaries and Afosu Stream.

Numerous separate surface water sampling events have been completed at the Akyem Gold Mining Project site since 2001. Water quality results show that streams and rivers generally have moderate conductivity, near neutral pH (some samples are slightly acidic), low dissolved oxygen, warm temperatures, and moderate turbidity. The presence of clay and silt throughout much of the Study Area, as well as human activities, can cause elevated sediment levels in surface water.

Inorganic parameters and nutrient concentrations (e.g., nitrate, nitrite, and phosphate) are generally low (mean concentrations of 1, 2 and 0 milligrams per litre (mg/L), respectively); however, there are instances where nitrate and nitrite concentrations have exceeded their standards (10 mg/L and 1 mg/L, respectively). Maximum nitrate concentrations were measured in Afosu Stream (14.5 mg/L) and Mamang River tributaries (35 mg/L). Maximum nitrite concentrations were measured in Afosu Stream (67 mg/L), Mamang River tributaries (151 mg/L), and Pra River tributaries (20 mg/L). Free cyanide was detected at concentrations exceeding the standard (0.01 mg/L) at two stations in 2001 (0.031 mg/L in Afosu Stream and 2.83 mg/L in the Pra River), but not in subsequent samples. Microbiological analysis of surface water collected near villages shows elevated levels of fecal coliform bacteria, with maximum concentrations ranging from 500 to 1,600 Most Probable Number per 100 millilitres (MPN/100mL) (**Table C4-5, Annex C4**). Fluoride exceeded its standard (1.5 mg/L) once at one surface water station on a Mamang River tributary (3.6 mg/L).

Metals in most surface water samples are either present at concentrations below Ghanaian drinking water standards or below laboratory detection limits (**Tables C4-4** and **C4-5, Annex C4**). Some samples from various locations (primarily the Mamang River drainage) exhibited elevated total metal concentrations, likely associated with colloidal sediment (clay) in the surface water. The elevated total metal concentrations occurred for the following analytes:

- Aluminium (concentrations ranging from 8 to 27.5 mg/L),
- Antimony (maximum concentration of 0.01 mg/L),
- Arsenic (concentrations ranging from 0.0144 to 0.4 mg/L),
- Barium (maximum concentration of 5.936 mg/L),
- Cadmium (maximum concentration of 0.01 mg/L),
- Chromium (maximum concentration of 0.16 mg/L),
- Copper (concentrations ranging from 0.89 to 4.8 mg/L),
- Iron (concentrations ranging from 21 to 130 mg/L),
- Lead (concentrations ranging from 0.0119 to 0.0126 mg/L),
- Manganese (concentrations ranging from 2 to 48 mg/L),
- Mercury (maximum concentration of 0.002 mg/L),
- Nickel (concentrations ranging from 0.01 to 1.0 mg/L),
- Selenium (concentrations ranging from 0.01 to 0.03 mg/L) and
- Zinc (concentrations ranging from 1.1 to 6.1mg/L).

Some samples contained elevated dissolved metals for the following analytes (**Table C4-5, Annex C4**):

- Aluminium (concentrations ranging from 1.1 to 3.5 mg/L),
- Arsenic (maximum concentration of 0.01 mg/L which is the Ghana drinking water standard),
- Iron (concentrations ranging from 1.4 to 14.6 mg/L) and
- Manganese (concentrations ranging from 0.12 to 2 mg/L).

Springs and Seeps

Three spring and seep surveys were conducted in 2007 during early-March, late-July, and mid-November. The spring and seep surveys were scheduled to evaluate dry period conditions (March), primary wet season conditions (July), and secondary wet season conditions (November). A total of 10 spring/seep locations were established for the monitoring programme (**Table 3-13** and **Figure 3-9**). Source seeps or seep complexes for the Yaya, Adentosu, Sentifa, Adenkyeresu, Akrawasu drainages and one unnamed drainage northeast of the proposed mine pit were identified, mapped, and sampled. The Abenasuo drainage was sampled as far upstream as could be reached.

No discrete springs were observed during the surveys. Shallow fractures do not appear to transmit significant groundwater, at least in the drainages surveyed. Highly mineralized seeps were not evident, and pH was in the range of 5.7 to 7.8 standard units. Total dissolved solids and metals concentrations generally were below drinking water quality standards (**Table C4-4, Annex C-4**). Some samples had exceedences of water quality standards for total aluminium (maximum concentration of 15 mg/L), total iron (maximum concentration of 7.7 mg/L), total lead (maximum concentration of 0.1 mg/L) and total manganese (maximum concentration of 0.13 mg/L). Water temperatures generally ranged from 24 to 26 °C. A summary of water quality samples collected and analyzed from the springs/seeps is included in **Annex C-4**.

TABLE 3-13
Spring and Seep Monitoring Sites

Spring/Seep Name	Location Description
ADET-1	Adentosu drainage near source
YAYA-1	Yaya drainage near source
AFOW-1	Unnamed drainage west of Afosu near source
SENT-1	Sentifa drainage at main site bedrock ridge
SENT-2	Sentifa drainage as reemergement seep
SENT-3	Sentifa drainage at 5 m high fall
SENT-4	Sentifa drainage near source
ADEK-1	Adenkyeresu drainage near source
AKRA-1	Akrawasu drainage near source
ABEN-1	Abenasuo drainage at base of foothills

Note: Locations shown on **Figure 3-9**.

Estimated flow at individual seep sites in 2007 typically was less than 0.0006 m^3/sec in July, with increased flow observed in November (up to 0.016 m^3/sec) as compared with July (Clear Creek Consultants 2008c). The seeps appear to be fed from diffuse groundwater flow (related to precipitation infiltration) transmitted through residuum, colluvium and minor alluvium at the headwaters of the drainages.

Spring and seep complexes were sampled in July and November 2007. Water quality was generally good, with neutral to slightly acidic pH, and low to moderate electrical conductance and dissolved solids. Some total and dissolved metals, including aluminium, iron, lead and manganese, exceeded their respective standards in several spring and seep samples **(Table C4-6, Annex C-4)**.

Surface Water Use

Because of the seasonal nature of stream flow in the Akyem area, surface water availability during the dry season is limited. During the wet season, water in streams and rivers in the Study Area is used for drinking, bathing, recreation, irrigation of crops and aquatic life support. During the dry season, fetch points are dug by hand in the channels in remote areas to obtain drinking water and for other uses when there is no flow in the streams.

To the southwest of the Study Area downstream of the Pra River and Mamang River confluence, water is pumped daily from the Pra River using a 1969 pumping station and treatment facility. This water is distributed by piping to four settlements (Brenase, Ofoase Kuma, Ofoase Pinyin, and Ofoase Zongo) that are located more than 18 kilometres from the Akyem site. The pumping station and treatment plant are operated by the Ghana Water Company. The Pra River is also a direct source of domestic water for various villages and hamlets located along its channel.

STREAMBED SEDIMENT

Streambed sediment samples obtained from six stations on the Mamang River and certain tributaries were collected and analyzed in October-November 2007 (Sample Stations SW-11, SW-16A, SW-17, SW-19, SW-28, and SW-31, **Figure 3-9**). All samples showed detectable concentrations of aluminium, iron, manganese and zinc (Clear Creek Consultants

2008b). Low concentrations of some other metals (i.e., arsenic, barium, beryllium, copper, lead, and mercury) were detected in selected samples, mostly those obtained from tributary channels. The grain size distribution for the six samples analyzed show predominantly fine-grained sediment (sand size or smaller). Graphs of sediment grain size distribution and concentrations for aluminium, iron, copper and zinc are included in **Annex C-4**.

GROUNDWATER

Information about groundwater conditions in the Study Area has been obtained from site observations, exploration drilling logs and monitoring wells/boreholes. Data from these sites include lithology, water elevations, aquifer hydraulic properties and groundwater chemistry.

Groundwater Monitoring Sites

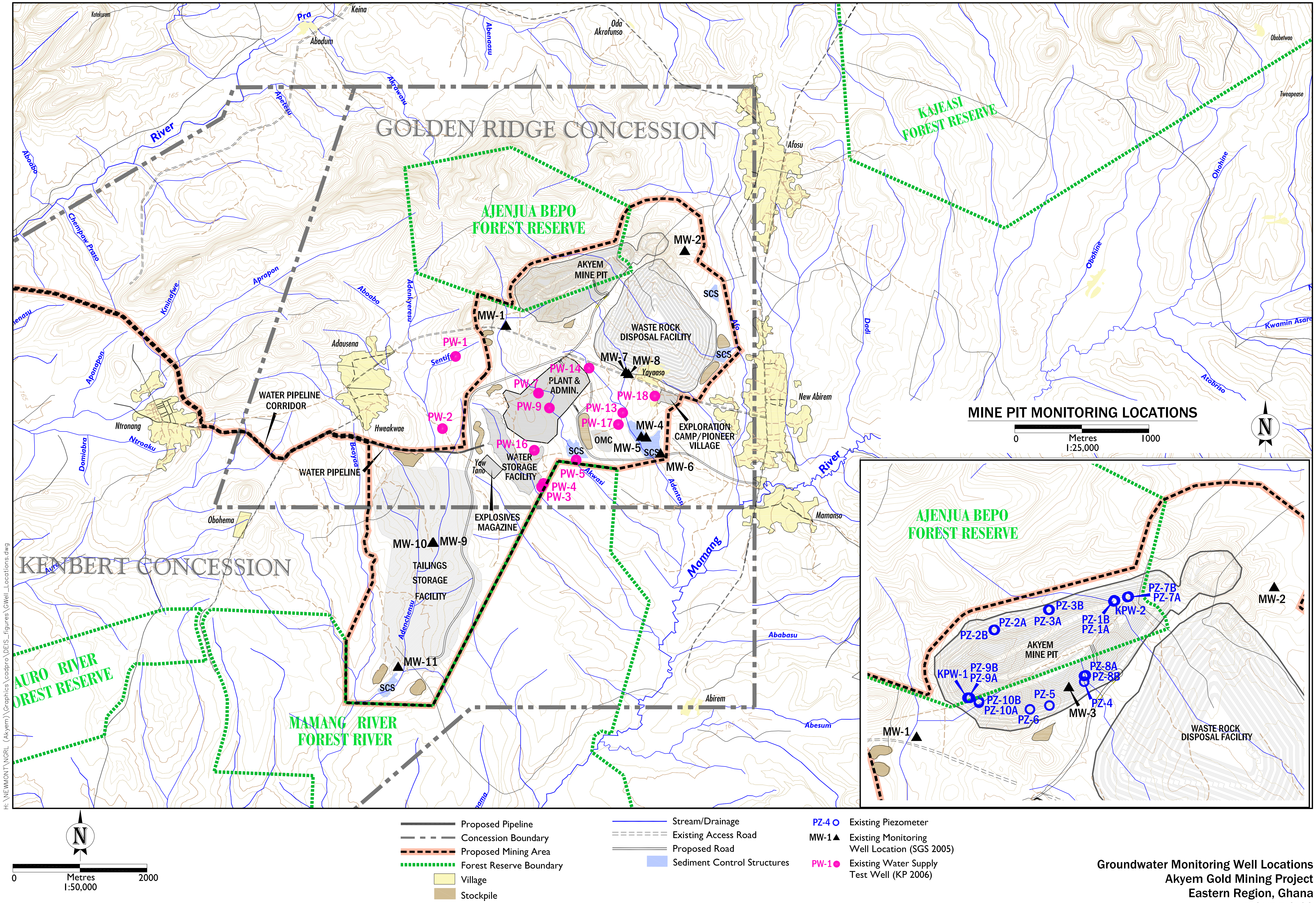
Table 3-14 lists groundwater monitoring wells completed/tested by SGS (2005) in the uppermost weathered bedrock zone (saprock) for the Akyem Gold Mining Project. These 11 well sites are located throughout the Study Area (**Figure 3-10**). All 11 wells are completed to depths of 61 metres or less. Village/community wells are described in a later section.

Table 3-15 lists 19 groundwater monitoring piezometers completed/tested by Golder Associates (2004b, 2006) in the proposed Akyem mine pit area. These piezometers are shown on **Figure 3-10**. Nine of the piezometers are completed in bedrock to depths between 100 and 200 metres. Two piezometers are completed in saprolite, and the remaining eight piezometers are completed in weathered bedrock (7 to 63 metres depth).

Eleven production/test wells were completed by Knight Piesold (2006) in the Study Area to investigate the potential for a water supply for the mine operations (**Table 3-16**). These well sites are shown on **Figure 3-10**. All of the wells are completed to depths between 41 and 63 metres in saprock and/or shallow bedrock.

Groundwater Hydraulic Characteristics

Primary porosity and permeability are low in geological formations of the Proposed Mining Area (mafic volcanics; greywacke and schist metasediments; and granitoids). Occurrence of groundwater is associated with fractures and weathered zones in bedrock formations. The typical aquifer system is composed of relatively low permeability weathered rock near ground surface, drained by fractures underneath. In the Proposed Mining Area, three general bedrock units are considered potential aquifers (from top to bottom): saprolite, saprock, and bedrock. Overall groundwater recharge rate is estimated at about 70 to 140 millimetres per year, which is 5 to 10 percent of total annual precipitation (1,370 millimetres) (Golder Associates 2004b). Groundwater discharge in the area occurs to wetland areas, springs, and some streams and rivers.



Groundwater Monitoring Well Locations
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-10

TABLE 3-14
Regional Groundwater Monitoring Wells in Saprock
Akyem Gold Mining Project

Monitoring Well Name	Lithology (all in Saprock)	Total Depth (metres)	Location
MW-1 (BH-13)	Greywacke	40	Southwest end of proposed mine pit
MW-2 (BH-1)	Greywacke	61	Southeast end of proposed mine pit
MW-3 (BH-2)	Greywacke	61	South-central end of proposed mine pit
MW-4 (BH-10)	Schist	43	South of proposed waste rock dump
MW-5 (BH-7)	Schist	24	South of proposed waste rock dump
MW-6 (BH-8)	Schist	39	South of proposed waste rock dump and west of senior staff village
MW-7 (BH-3)	Greywacke	45	Within footprint of proposed waste rock dump
MW-8 (BH-4)	Greywacke	31	Within footprint of proposed waste rock dump
MW-9 (BH-14)	Schist	54	Centre of proposed TSF
MW-10 (BH-16)	Schist	34	Centre of proposed TSF
MW-11 (BH-18)	Greywacke	60	South of proposed TSF

Note: See **Figure 3-10** for location of MW-wells. TSF = Tailings Storage Facility.
Source: SGS (2005)

Saprolite is deeply weathered and oxidized bedrock (up to about 60 metres thick) consisting of silt and silty clay. Saprolite generally is overlain by one to 5 metres of iron-rich clayey soil. The saprolite acts as a reservoir of unconfined groundwater that contributes water to underlying saprock and bedrock. Saprock typically is from one to 10 metres thick and represents a transition between the upper weathered saprolite and deeper fresh, unoxidized bedrock. The saprock zone typically is the first water-bearing unit that yields enough water to wells for domestic or other pumping needs.

Depth to groundwater in saprolite and saprock ranges from about 2 metres below ground surface in some low-lying areas to 50 metres or more in upland areas (Golder Associates 2004b). Saturated thickness of these units ranges from about 1 to 20 metres. In some upland areas, the saprolite and saprock are above the water table. The underlying bedrock generally is saturated and under confined conditions. A downward component of groundwater flow is evident from saprolite and saprock to underlying bedrock in most of the mine pit area (Golder Associates 2004b). In some lowland areas, however, there is an upward component of groundwater flow between bedrock and saprolite.

Groundwater flow generally follows local topography from upland to lowland areas. Regional groundwater generally flows from northeast to southwest. Water-bearing fractures have been noted in exploration borings in the mine pit area at depths greater than 80 metres.

The Akyem fault is a regional structure that separates the ore-bearing hanging-wall from the foot-wall. The structure would be exposed in the northern mine pit wall. Groundwater in this structural (graphite) shear zone occurs under confined or semi-confined conditions, but appears to have an overall low permeability except in some minor zones of broken rubble (Golder Associates 2004b).

TABLE 3-15
Groundwater Monitoring Piezometers in Mine Pit Area
Akyem Gold Mining Project

Piezometer Name	Lithology	Total Depth (metres)	Location
PZ-1A	Bedrock (Mafic Volcanics)	100	Proposed Mine Pit Area
PZ-1B	Saprolite	19.5	Proposed Mine Pit Area
PZ-2A	Bedrock (Mafic Volcanics)	200	Proposed Mine Pit Area
PZ-2B	Saprock	63	Proposed Mine Pit Area
PZ-3A	Bedrock (Mafic Volcanics)	103	Proposed Mine Pit Area
PZ-3B	Saprock	32.3	Proposed Mine Pit Area
PZ-4	Saprolite	14.5	Proposed Mine Pit Area
PZ-5	Saprock (Greywacke)	43	Proposed Mine Pit Area
PZ-6	Saprock (Greywacke)	50	Proposed Mine Pit Area
PZ-7A	Bedrock (Greywacke)	200	Proposed Mine Pit Area
PZ-7B	Saprock	12	Proposed Mine Pit Area
PZ-8A	Bedrock (Greywacke)	200	Proposed Mine Pit Area
PZ-8B	Saprock	7	Proposed Mine Pit Area
PZ-9A	Bedrock (Greywacke)	200	Proposed Mine Pit Area
PZ-9B	Saprock	21	Proposed Mine Pit Area
PZ-10A	Bedrock (Greywacke)	200	Proposed Mine Pit Area
PZ-10B	Saprock	17	Proposed Mine Pit Area
KPW-1	Bedrock	200	Proposed Mine Pit Area
KPW-2	Bedrock	150	Proposed Mine Pit Area

Note: See **Figure 3-10** for location of PZ-piezometers and KPW-wells.
Source: Golder (2004b, 2006)

TABLE 3-16
Groundwater Production/Test Wells
Akyem Gold Mining Project

Piezometer Name	Lithology	Total Depth (metres)	Location
PW-1	Saprock	48	Along Proposed Water Line
PW-2	Saprock	45	West of Proposed Plant Site
PW-3	Greywacke Saprock	41	Proposed Plant Site
PW-4	Schist/Greywacke Saprock & Bedrock	49	Proposed Plant Site
PW-5	Greywacke Saprock	54	Proposed Batch Plant
PW-7	Greywacke Saprock & Bedrock	47	Proposed Plant Site
PW-9	Greywacke Saprock & Bedrock	49	Proposed Plant Site
PW-13	Greywacke Saprock & Bedrock	46	Proposed Sr. Staff Village
PW-14	Schist/Greywacke Saprock & Bedrock	54	Road Construction Area
PW-16	Greywacke Saprock & Bedrock	53	Proposed Plant Site
PW-18	Greywacke Bedrock	63	Waste Rock Dump

Note: See **Figure 3-10** for location of PW-wells.
Source: Knight Piesold (2006)

Aquifer tests have been conducted on various sets of piezometers and monitoring wells at the Study Area. Summary tables of these tests are included in **Annex C-4**. A graph is presented in **Annex C-4** that shows average hydraulic conductivity for all tests conducted in the following lithologic units (from upper to lower depths):

- Saprolite: 4.5×10^{-7} metres per second (m/sec)
- Saprolite/Saprock: 4.7×10^{-7} m/sec
- Saprock: 2.4×10^{-5} m/sec
- Bedrock: 3.5×10^{-6} m/sec
- Graphite Shear Zone: 1.5×10^{-7} to 3.6×10^{-7}m/sec

Depth to groundwater was greatest during February-April and shallowest during October-November (SGS 2005) for the 11 MW-wells. Average annual hydrographs of groundwater elevations and monthly precipitation for selected wells measured in 2004-2008 are included in **Annex C-4**.

Groundwater Quality

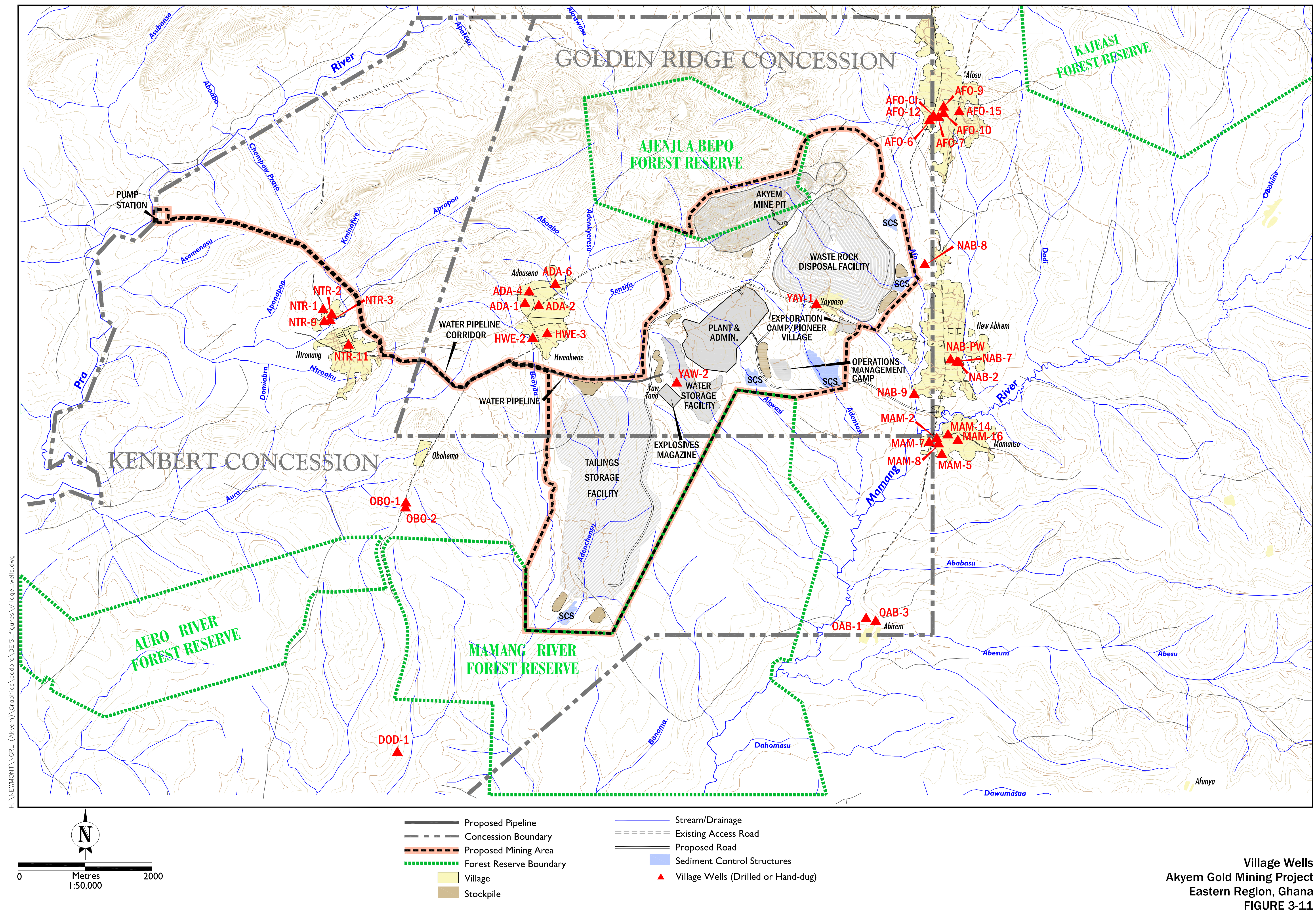
Monitoring Wells

A groundwater quality monitoring programme, started in 2004 and continued through 2007, consisted of collecting water samples for analysis of chemical constituents from the 11 MW-wells (**Table 3-14**). Results of groundwater analyses from monitoring wells are summarized in **Annex C-4**. Groundwater quality results from village wells are discussed in a later section. Drinking water quality standards or guidelines for the parameters analyzed are presented in **Annex C-4**.

In general, groundwater in Proposed Mining Area monitoring wells exhibits variable electrical conductivity and exhibits acidic to neutral pH. Suspended solids and turbidity were elevated in some samples. Most metal concentrations are generally below or near laboratory detection limits used for this project. Several metals were present in some unfiltered samples at concentrations exceeding drinking water standards, including aluminium, antimony, arsenic, cadmium, chromium, iron, lead, manganese, nickel, selenium, and thallium. Elevated concentrations of total metals typically are associated with suspended solids in the water samples. Metals in filtered samples from monitoring wells that also exceeded standards include arsenic, iron, and manganese. Total and fecal coliform bacteria were detected in one monitoring well.

Village Wells

Sampling of village water supply wells in the Study Area was initiated in 2001, with results reported by SGS (2005). During 2007, Clear Creek Consultants (2008d) completed three rounds of sampling of village wells (March; July-August; and September). Each of the three 2007 sampling events included collection of water samples for laboratory analysis from 16 drilled village wells and eight hand-dug wells (**Table 3-17**). Previous sampling events generally included only seven village wells. All 36 village wells identified during the 2007 inventory by Clear Creek Consultants (2008d) are shown on **Figure 3-11**.



Village Wells
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-11

TABLE 3-17
Village Wells Monitored at Akyem Gold Mining Project

Well Name	Location	Well Type
ADA-1*	Adausena	Hand dug
ADA-2*	Adausena	Drilled/hand pump
ADA-4	Adausena	Drilled/hand pump
ADA-6	Adausena	Drilled/hand pump
AFO-6	Afosu	Hand dug
AFO-7*	Afosu	Hand dug
AFO-9	Afosu	Hand dug
AFO-10	Afosu	Hand dug
AFO-12*	Afosu	Drilled/hand pump
AFO-15*	Afosu	Drilled/hand pump
AFO-C1*	Afosu –Cocoa Institute	Drilled/downhole pump
DOD-1*	Dodowraso	Drilled/hand pump
HWE-2*	Hweakwae	Drilled/hand pump
HWE-3*	Hweakwae	Drilled/hand pump
MAM-2*	Mamanso	Hand dug
MAM-5	Mamanso	Hand dug
MAM-7	Mamanso	Hand dug
MAM-12	Mamanso	Hand dug
MAM-14*	Mamanso	Drilled/hand pump
MAM-16*	Mamanso	Drilled/hand pump
NAB-2	New Abirem	Hand dug
NAB-7*	New Abirem	Hand dug
NAB-8*	New Abirem	Hand dug
NAB-9*	New Abirem	Hand dug
NAB-PW*	New Abirem – Pipe Water	Distribution Pipe
NTR-1	Ntronang	Hand dug
NTR-2*	Ntronang	Hand dug
NTR-3	Ntronang	Hand dug
NTR-9	Ntronang	Hand dug
NTR-11*	Ntronang	Drilled/hand pump
OBO-1*	Obohema	Drilled/hand pump
OBO-2*	Obohema	Drilled/hand pump
OAB-1*	Old Abirem	Hand dug
OAB-3*	Old Abirem	Drilled/hand pump
YAW-2*	Yaw Tano	Drilled/hand pump
YAY-1*	Yaayaaso	Drilled/pumped
YAY-2*	Yaayaaso	Drilled/bailed

Note: See **Figure 3-11** for village well locations with an asterisk. Asterisk * indicates those wells subject to laboratory analysis of water samples in 2007.
Source: Clear Creek Consultants (2008d)

Results of groundwater analyses from village wells are summarized in **Annex C-4**. Drinking water quality standards or guidelines for the parameters analyzed are also presented in **Annex C-4**. For village well samples collected in 2007 by Clear Creek Consultants (2008d), five of 24 hand-dug well samples contained nitrate above the standard; however, no drilled well samples exceeded the standard. Field pH ranged from slightly acidic (around 5.0) to neutral, and conductance ranged from low to moderate. Total coliform bacteria were detected in 21 of 24 hand-dug well samples, as well as 15 of 52 drilled well samples. Fecal coliform bacteria were detected in 10 of the hand-dug well samples, as well as two of the 52 drilled well samples.

Some unfiltered samples from village wells exhibited metal concentrations that exceeded drinking water standards, including aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, and zinc. The presence of clay and silt in many village wells indicates that these wells may not be completely developed or properly screened, and turbidity may be at least partially responsible for some elevated metals concentrations in unfiltered samples. Filtered samples from a few village wells contained elevated metals concentrations, including aluminium, arsenic, cadmium, iron, manganese, and nickel.

In general, exceedences of drinking water standards were more common in hand-dug wells versus drilled wells, especially for electrical conductivity, aluminium, total dissolved solids, nitrate and faecal coliform. Exceedences of drinking water standards for arsenic, manganese and selenium were more common in drilled wells than hand-dug wells.

Groundwater Use

Boreholes or wells are the main source of water for residents in the Study Area. **Table 3-17** is a list of village wells that have been included in the 2007 groundwater monitoring programme for the Akyem Gold Mining Project. A total of 36 village wells and one distribution pipe are included in the list. Depth and yield of the village wells are unknown due to lack of well completion reports. Many people still obtain drinking water from boreholes fitted with hand-pumps. A majority of households draw their water from unprotected sources, exposing residents to water-borne infections and other health hazards. Vendor trucks also supply potable water to some areas.

3.2.4 SOIL RESOURCES

Soil in the Proposed Mining Area was evaluated through review of data collected in conjunction with baseline soil surveys. The data were compared to other soil data in Ghana and elsewhere in the world to assess the existing conditions of the resource relative to soil in similar settings. Summaries of laboratory results and other data germane to this discussion are included in **Annex C-5.**

SOIL SURVEY

Soil within the Proposed Mining Area is described in three soil survey reports. The entire Pra River Basin was initially mapped as part of a survey not associated with this project (Obeng 2003). Mapping in the vicinity of the Proposed Mining Area was updated as part of the soil investigation undertaken by SGS (2004e). The most recent soil survey, completed in 2008, further refined map unit boundaries and identified characteristics of the soil types in the Proposed Mining Area (Geomatrix and Soil Research Institute 2008). This 2008 soil survey and resultant soil map (**Figure 3-12**) is the primary basis for the assessment of soil resources presented in this document.

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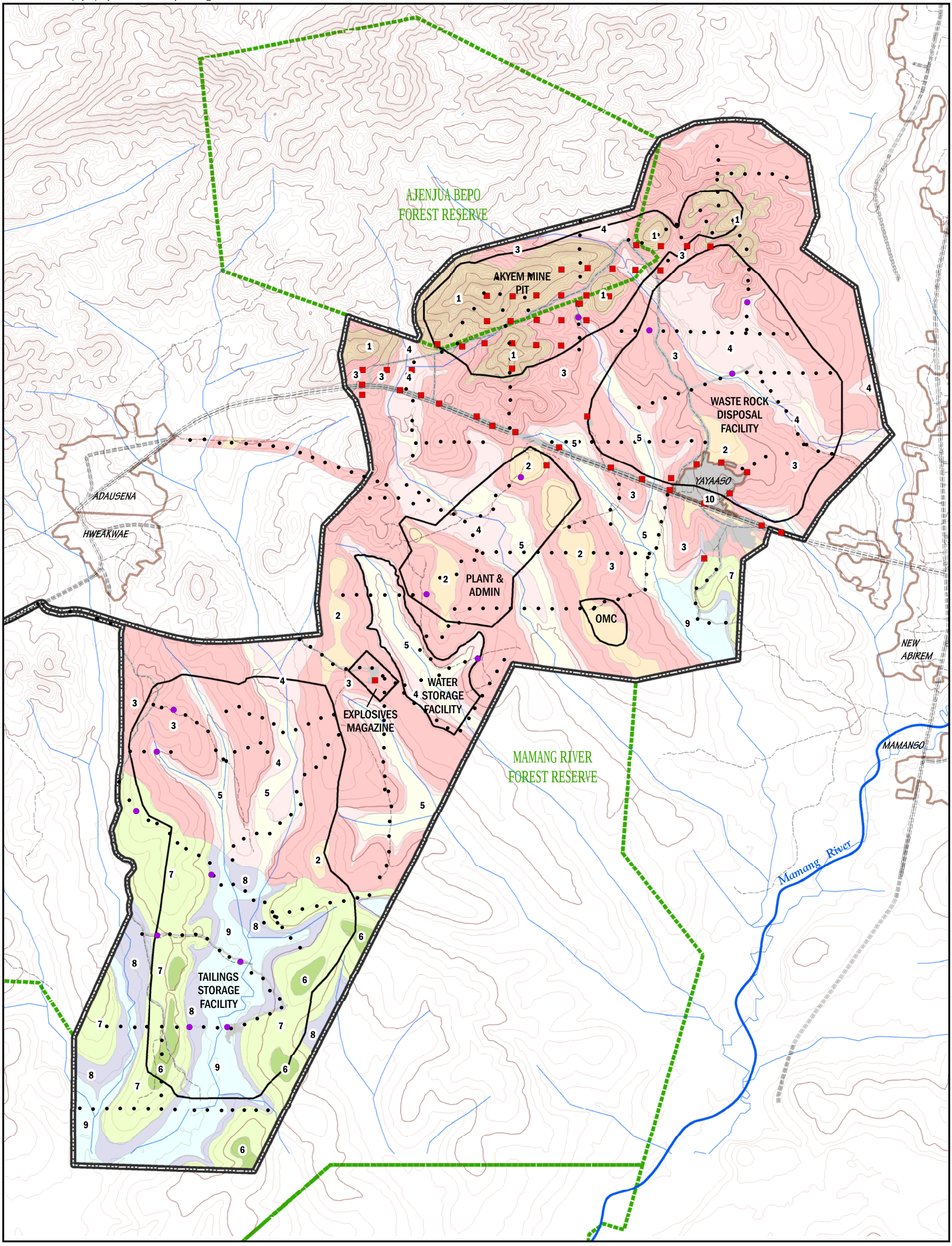


N

0 1,000

Metres
1:25,000

Proposed Mining Area
Proposed Mine Facilities
Stream/Drainage
Roads
Tracks/Paths
Villages
ForestReserve
Agronomic and Elemental Samples
Elemental Samples
Observation Point

SOIL SAMPLES AND SOIL TYPES

1 - Bekwai-Kobeda Complex
2 - Bekwai
3 - Nzima
4 - Kokofu
5 - Temang-Oda Complex
6 - Swedru
7 - Nsaba
8 - Akroso
9 - Nta-Ofin Complex
Existing Disturbance

Soils Map of Proposed Mining Area
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-12

Eleven upland and lowland soil series developed from lower Birimian and granitic materials comprise nine map units within the Proposed Mining Area. Names, geologic origins (i.e., parent materials), and areal extents of the map units within the Proposed Mining Area are shown in **Table 3-18.** The natural topographic sequences of the soil series and their characteristics are summarized in **Table 3-19**. Additional data, including laboratory results and taxonomic classification of soil series, are presented in **Annex C-5.**

TABLE 3-18
Distribution of Soil Series within Akyem Mining Area

Rock Origin	Map Unit (Series or Complex)	Map Unit Symbol	Extent of Map Unit Proposed Mining Area	
			hectares	%
Lower Birimian	Bekwai-Kobeda Complex	1	113.2	5.9
	Bekwai	2	73	3.8
	Nzima	3	855	44.6
	Kokofu	4	263	13.7
	Temang-Oda Complex	5	147.4	7.7
		Subtotal	**1451.6**	**75.8**
Granitic and Similar Materials	Swedru	6	20.6	1.1
	Nsaba	7	200.1	10.4
	Akroso	8	82.7	4.3
	Nta-Ofin Complex	9	111.1	5.8
		Subtotal	**414.4**	**21.6**
Existing Disturbances		10	**49.1**	**2.6**
		TOTAL ALL SOIL	**1915**	**100**

Source: Geomatrix and Soil Research Institute (2008).

TABLE 3-19
Typical Characteristics of Soil Series

Parent Mat.		Series	Position	Dr. [1]	Colors and Textures		Coarse Fragments [2]	Other Notable Characteristics [3]
					Topsoil	Subsoil		
LOWER BIRIMIAN	Residuum & Colluvium	Kobeda	Steep slopes & high summits	W - SE	Dark Brown Clay Loam	Red to Reddish Brown Silty Clay & Clay	**Topsoil** - Very few to none. **Subsoil** - Common to abundant fine to medium concretions & gravels.	Often highly eroded. Bedrock occurs at 50 - 100cm. Low available nutrients and effective water holding capacity.
		Bekwai	Upper slopes & moderate summits	W	Reddish Brown to Brown Clay Loam	Reddish Brown to Red Clay & Clay Loam	**Topsoil** - Very few to none. **Subsoil** - Common to many fine to medium concretions & gravels.	Often eroded. Low nutrient availability and moderate effective water holding capacity. Very Acidic subsoil. Plinthite may occur at depths over 100cm.
		Nzima	Middle to upper slopes & low divides	MW - W	Brown & Dark Brown Clay Loam & Loam	Strong Brown Clay	**Topsoil** - Very few to none. **Subsoil** - Common to many fine to medium concretions & gravels.	High clay content in subsoil. Very acidic. Plinthite may occur at depths over 100cm.
		Kokofu	Middle to lower slopes	I - MW	Brown to Yellowish Brown Clay Loam & Loam	Yellowish Brown Clay Loam & Clay	**Topsoil** - Very few to none. **Subsoil** - Few fine to medium concretions.	High clay content in subsoil. Very acidic. Relatively low cation exchange capacity. Plinthite common below 60 cm. Highly erodible subsoil.
	Alluvium	Oda	Valley bottoms & flood plains	P - I	Grayish Brown & Brown Clay Loam & Loam	Brown to Yellowish Brown Clay & Clay Loam	**Topsoil** - Very few to none. **Subsoil** - Very few to none. All fragments nearly sand size.	Weakly developed. Often saturated with mottled subsoil. Relatively low observed rooting depth. All materials are highly erodible.
		Temang	Valley bottoms & flood plains	P - I	Dark Grayish Brown to Brown Loam to Loamy Sand	Grayish Brown to Brown Sandy Clay Loam to Fine Sand	**Topsoil** - Very few to none. **Subsoil** - Very few to many fine to medium gravels & concretions.	Weakly developed. Often saturated with mottled subsoil. Relatively low clay content, cation exchange capacity, and available nitrogen.
GRANITES AND SIMILAR MATERIALS	Residuum & Colluvium	Swedru	Upper slopes & moderate summits	W	Dark Brown Sandy Loam	Reddish Brown to Red Sandy Clay Loam & Sandy Clay	**Topsoil** - Very few to none. **Subsoil** - Few to common gravels.	Often somewhat eroded. Good available nutrients relative to other series. Plinthite common below 70 cm. Greater rooting depth than most series.
		Nsaba	Middle to upper slopes & low divides	MW - W	Brown Sandy Loam & Loam	Brown Sandy Clay & Sandy Clay Loam	**Topsoil** - Very few to none. **Subsoil** - Common to many medium & fine gravels.	Very acidic. Relatively low cation exchange capacity. Plinthite common below 70cm.
		Akroso	Middle to lower slopes	I - MW	Dark Brown Sandy Loam	Yellowish Brown Sandy Loam & Sandy Clay Loam	**Topsoil** - Very few to none. **Subsoil** - Very few to none.	Relatively low clay content. Highly erodible subsoil. Plinthite common below 70 cm.
		Nta	Very gentle lower-slopes & outwash areas	I - P	Dark Brown Sandy Loam	Yellowish Brown Sand to Sandy Clay Loam	**Topsoil** - Very few to none. **Subsoil** - Few to none.	Weakly developed. Often saturated with mottled subsoil. Relatively low clay content, nitrogen, and organic matter. Greater rooting depth than most series.
	Alluvium	Ofin	Valley bottoms & flood plains	P - I	Grayish Brown Sandy Loam	Grayish to Yellowish Brown Sandy Loam	**Topsoil** - Very few to none. **Subsoil** - Very few to none.	Weakly developed. Often saturated with mottled subsoil. Relatively low clay content. Lowest rooting depth.

1 - Drainage (Dr.): Poor = P, Imperfect = I, Moderately Well = MW, Well = W, Somewhat Excessive = SE.
2 - The coarse fragment content described reflects the findings of field observation rather than laboratory analyses, which may detect additional fine gravel and concretions.
3 - The term "relative" refers to comparison of the subject soil's characteristics to the other series in the Study Area.

GENERAL SOIL CHARACTERISTICS

Under tropical environmental conditions, the soil of the Proposed Mining Area has developed to a mature stage with typical morphological characteristics. Parent material and topographic position are the dominant factors influencing soil variability in the Proposed Mining Area. The resultant characteristics affect use of the soil for agriculture purposes.

Natural processes and intensive agricultural practices employed throughout much of the surveyed area have resulted in soil erosion and low soil nutrient content. In tropical soil types such as those surveyed, nutrient cycling naturally occurs very rapidly. Where vegetation is cleared or fallow is burned, nutrients released into the soil solution are not consumed as effectively and are easily leached from the soil. The high rainfall, intense weathering of soil and intense agricultural practices has resulted in soil that is acidic and low in plant nutrients. Natural processes and clearing for agriculture have resulted in some highly eroded areas, especially on middle to upper slopes and summits. Effective fertilization and anti-erosion methods are needed if the soil is to be used for prolonged agricultural production without fallow.

Most of the series on summits of low-lying uplands and ridges to middle slopes are well to moderately well drained and moderately deep to very deep. These series have fair to moderate moisture retention capacity as the result of their high subsoil clay contents. However, summits and slopes of steep-sided mountains in the northern-most portions of the Project Boundary are comprised of shallow to deep, highly stony and gravely series that become droughty soon after rain and are susceptible to erosion. Shallow bedrock and exposures are common on the steepest slopes. While most steep slopes occur in the Forest Reserve and are not cultivated, lower summits and less steep slopes are commonly used for agriculture.

Profiles of middle and lower slope series often have fewer coarse fragments and have plinthic horizons in their subsoil. Plinthite materials have irreversibly hardened to petroplinthite (ironstone) where these soil types have gone through periodic wet and dry cycles, Petroplinthite is occasionally observed in soil as hard fragments or in large blocks at the site of historic excavations or escarpments. Middle and lower slope soils are extensively used for agriculture.

Soil series in the valleys are deep to very deep, sandy to clayey, imperfectly to poorly drained, mostly gray with mottles. While coarse sand is common, stones and gravels are less common than in upland soil. Valley bottoms are susceptible to flooding and water logging during wet seasons. These soils are extensively used for agriculture.

Additional discussion regarding geologic and landform associated with soils in the Proposed Mining Area is included in **Annex C-5**.

EROSION HAZARD

Potential erosion of soil in the Proposed Mining Area from wind is minimal due to the high clay content and low wind speeds. However, erosion from water can affect the ability of the landscape to sustain agricultural production through loss of topsoil and growth medium

and watershed function. As a result of farming and other intensive land uses, soil in the survey area has experienced erosion, especially on upper slopes and the steep slopes in the Ajenjua Bepo Forest Reserve. Soil erosion occurs on exposed surfaces and increases with rainfall intensity. Soil erosion control measures associated with the Project are described in Section 5 of the EIS (Mitigation Measures). Soil series with low infiltration rates, low plant cover, or located on steep slopes are especially vulnerable to water erosion.

Results of the agronomic analyses and profile descriptions were used to evaluate the erodibility of the soil series in the Proposed Mining Area independent of their landscape positions. The Bekwai topsoil and subsoil, Nzima subsoil, and Nta topsoil and subsoil were among the least erodible, with all other soil analyzed being highly erodible. Results show that the upland soil is less erodible than the lower slope and valley bottom soil. This is primarily due to the effects of coarse fragments, which are more prevalent in upland soil, especially subsoil horizons. The data also indicate that subsoil of most series is less erodible than surface materials and lower Birimian series are slightly more erodible than Granitic series. Additional information regarding erodibility is provided in **Annex C-5**.

AGRICULTURAL SUITABILITY

The 2008 soil survey (Geomatrix and Soil Research Institute 2008) assessed the suitability of the soil in the Proposed Mining Area for rain-fed agricultural uses according to United Nations Food and Agricultural Organisation (FAO 1976) methods, which are based primarily on the morphological properties of the soils and landscape characteristics. The series were rated according to the orders of suitable (S), non-suitable (N) and further separated into the following suborders: highly suitable (SI), moderately suitable (S2) marginally suitable (S3), presently not suitable (N1) and permanently not-suitable (N2). The major limitations affecting the assessments were soil depth, content of gravels and stones, infertility or textural problems (s), soil erosion hazard (e), and wetness and flooding problems (w). Six of the soil series in the Proposed Mining Area were determined to be "moderately suitable" for rain-fed agricultural use, four were determined to be "marginally suitable" and one was identified as "permanently not-suitable." **Annex C-5** includes additional discussions regarding this analysis.

SUITABILITY FOR USE IN RECLAMATION

The 2008 soil observations were evaluated to determine the thicknesses and depths of the materials most suitable for use in reclamation. This evaluation assumed that the presence of bedrock, plinthite, weakly developed soil and saturated materials would generally render the soil unsuitable and determine the lower-limits of potential salvage. Results of this evaluation are presented in **Table 3-20**.

The suitability of soil for use in reclamation is ultimately dependent upon the objectives and methods of reclamation. Soil types with different characteristics may be equally suitable for agricultural production or other uses depending on the type of crops to be grown on each, the post mine landscape configuration, site specific requirements for soil cover and rooting depth, and soil handling plans employed. As such, final evaluations of suitability will be performed in conjunction with development of the reclamation plan for the selected project development alternative.

TABLE 3-20
Average Thicknesses of Most Suitable Soil Materials
(centimetres)

Map Unit	Topsoil [1]	Subsoil [2]	Most Notable Limiting Factors in Subsoil
Bekwai-Kobeda Complex[3]	8	35	Bedrock and high coarse fragment content
Bekwai	12	90	Plinthite
Nzima	14	85	Plinthite
Kokofu	17	50	Plinthite
Temang-Oda Complex	24	0 *	Weakly developed and saturated materials
Swedru	12	55	Plinthite
Nsaba	16	55	Plinthite
Akroso	18	50	Plinthite
Nta-Ofin Complex	21	0 *	Weakly developed and saturated materials

1 - Topsoil depth determined by the average thickness of A horizons (e.g., A, AB, AC) observed at all observation points.
2 - Subsoil thickness estimated from review of typical pedon descriptions. Partial pedon descriptions not adequate to accurately estimate thickness.
3 - Salvage estimated due to prevalence of escarpments and rock outcrops.

* Some weakly developed soil materials may be available for salvage depending on season and propose use.

3.3 HUMAN ENVIRONMENT

The human environment within the Study Area includes individuals living and working in small communities located relatively near the Proposed Mining Area as well as in hamlets and individual residences in more rural areas proximal to the Proposed Mining Area. Several aspects of the human environment and social conditions present in the Study Area are described herein, including baseline noise levels, visual resources, land use, access and transportation systems, cultural resources and social and economic resources.

3.3.1 NOISE

Noise in the Study Area was evaluated through on-site measurements to determine background conditions for a variety of locations and times. These data are compared to EPA Guidelines and international standards to provide a sense of the existing conditions in the Study Area. Definitions of noise terminology, summaries of subjective noise levels and other information and data germane to this discussion are included in **Annex C-6**.

NOISE GUIDELINES

EPA established ambient noise level guidelines for application in Ghana (Ghana EPA 2005). The guideline limit for residential areas with negligible or infrequent transportation is 55 decibels between 0600-2200 hours and 48 decibels between 2200-0600 hours. The guideline limit for heavy industrial areas, presumably applicable to the Proposed Mining Area, is 70 decibels. Noise levels above 45 decibels may impair sleep, while 70 decibels leads to emotional upset, irritability and other tensions (Home Page Ghana 2005). Ambient noise level guidelines are summarized in **Table 3-21.**

Table 3-21
Ambient Noise Level Guidelines

Zone	Description of Area of Noise Reception	Permissible Noise Level (dBA)	
		Day: 0600-2200 hours	Night: 2200-0600 hours
A	Residential areas with negligible or infrequent transportation	55	48
B1	Educational (school) and Health (hospital, clinic) facilities	55	50
B2	Areas with some commercial or light industry	60	55
C1	Areas with some light industry, places of entertainment or public assembly, and places of worship such as churches and mosques	65	60
C2	Predominantly commercial areas	75	65
D	Light industrial areas	70	60
E	Predominantly heavy industrial areas	70	70

Note: dBA = A weighted decibels
Source : Ghana EPA (2005)

The World Health Organisation (WHO) also has established noise level guidelines for various land uses. For residential dwellings or areas used for human habitation and sleep, WHO (1999) recommends that sound levels be no higher than 50-55 decibels for 16 hours of exposure during daytime and 45 decibels for 8 hours of exposure at night. WHO (1999) also recommends that persons should never be exposed to a maximum sound level (fast L_{max}) greater than 110 decibels, nor a peak sound pressure level (unweighted instantaneous level, not fast L_{max}) greater than 140 decibels for adults and 120 decibels for children (WHO 1999).

The generally accepted standard in most countries, including Ghana, for protecting hearing is a noise level of no more than 85 decibels for an 8-hour daily exposure. In Ghana, there is no law governing worker exposure to hazardous noise levels at mine sites. However, the mine's inspectorate uses a noise level of 85 decibels for an 8-hour daily exposure as the standard when advising mining companies on the importance of hearing protection (Amedofu 2002).

EXISTING NOISE LEVELS

The Study Area has few existing industrial noise sources. A primary roadway extends north-to-south from Afosu to Mamanso (and beyond) along the eastern boundary of the Proposed Mining Area with a second extending east-to-west from New Abirem to Ntronang (and beyond) (**Figure 3-1**). Relatively light traffic is present on these roadways. Other potential sources for background noise in the Study Area occur within communities as well as with those produced by natural sources of sound including birds, crickets, frogs, roosters, goats and, to a lesser degree, wind.

Sound levels were measured at sites within several communities that may be impacted by the Project, including Mamanso (Station M-1), New Abirem South (Station M-2), New Abirem North (Station M-3), Afosu (Station M-4) Adausena (Station M-5) and Hweakwae (Station M-6). Locations of these communities are shown on **Figure 3-1**. Noise levels at

these sites are expected to be somewhat higher than remotely located residences in the Study Area due to more concentrated noise produced from human activities and automobiles. However, the background noise environment, even in the populated centres, is often dominated by noise from natural sources. Because of this, sound levels in the unpopulated areas are likely to be similar to the populated areas much of the time.

Long-term sound level measurements were obtained during May and October 2007 at the stations listed above to characterize the existing sound levels in the five population centres nearest the proposed Project. **Annex C-6** includes descriptions of how the tests were conducted. In general, the tests indicated baseline sound levels in the communities tested are the result of both man-made and natural sources. Man-made sources of sound include: music amplification systems at celebrations, funerals and church services; occasional vehicles; children; and people going about their daily activities. Absent from the existing noise environment, for the most part, is noise from steady roadway traffic, machinery and industry. Natural sources of sound that are dominant for baseline conditions include birds, crickets, frogs, roosters, goats and, to a lesser degree, wind. The most consistently noted audible source of sound throughout the Study Area was crickets.

Measured sound levels at each of the five communities studied are summarized in **Table 3-22**. The measurement data are shown as a range of hourly sound levels taken during either daytime (i.e., 0600 to 2200 hours) or night time (i.e., 2200 to 0600 hours) hours. A more detailed accounting of the results of the noise studies, by community, is included in **Annex C-6**.

The results indicate noise levels were generally louder during the October measurements as compared to May; the reasons for this are not completely understood. Weather data were analyzed and no pattern was evident with any of the measured parameters, such as wind and rain that correlated to the periods of high sound levels. One possible explanation is that the high sound levels were due to crickets, because the sound levels spike at sundown (between 1800 and 1900 hours) when temperatures decrease and crickets become more active.

The highest noise levels measured during the daytime (0600 to 1000 hours) were often higher than the 55-decibel daytime residential guideline and sometimes exceeded the industrial noise guideline of 70-decibels. Similarly, the highest night time noise levels frequently exceeded the 48-decibel night time residential guideline. The lowest daytime and night time levels measured were generally lower than the 55-decibel (daytime) and 48-decibel (night time) guidelines except at Stations M1, M5 and M6 during the October survey, when the lowest noise levels measured during the night time period (49, 56, and 49 decibels) exceeded the night time guideline.

3.3.2 VISUAL RESOURCES

Topography in the Study Area consists of valleys bound by rolling hills. Elevations range from 100 metres above mean sea level (amsl) in the valleys to 300 metres amsl along the ridgelines. The highest elevation in the Study Area is 480 metres amsl in the Ajenjua Bepo Forest Reserve. The hills and valleys in the Study Area are covered in dense vegetation exhibiting varying shades of green. Undulating horizontal lines visible through the atmospheric haze represent the hills relative to depth of field. Texture, pattern, and colour

are influenced by the dominance of vegetation. The only breaks in the natural homogenous pattern are the palm plantations and groves of orange trees. Villages offer a contrast to this view by being devoid of nearly all vegetation and exposing reddish yellow soil. Those viewing the area are primarily local residents; tourism and recreation are not prominent activities in the Study Area.

TABLE 3-22
Existing Sound Levels (dBA) - 2007
Akyem Gold Mining Project Study Area

SLM Location		Dates	Time	Range of L90	Range of Leqs	Ghanaian Residential Guidelines
M1		May 16-23	Daytime	38-61	51-78	55
			Night time	41-62	44-66	48
		October 8-15	Daytime	41-83	51-84	55
			Night time	44-68	49-74	48
M2		May 1-8	Daytime	30-52	40-78	55
			Night time	34-50	39-59	48
		September 12-19	Daytime	30-69	40-79	55
			Night time	41-62	48-63	48
M3		May 1-8	Daytime	38-55	46-79	55
			Night time	37-55	41-64	48
		September 12-19	Daytime	35-66	45-81	55
			Night time	41-62	46-63	48
M4		May 16-23	Daytime	42-55	49-82	55
			Night time	37-55	37-62	48
		October 8-15	Daytime	35-66	52-80	55
			Night time	41-62	47-75	48
M5		June 12-19	Daytime	42-55	48-78	55
			Night time	30-49	43-70	48
		October 17-24	Daytime	40-78	51-81	55
			Night time	41-71	56-74	48
M6		June 12-19	Daytime	38-65	49-78	55
			Night time	38-57	42-60	48
		October 17-24	Daytime	40-69	48-83	55
			Night time	44-60	49-64	48

Notes:
The Leq is the "energy-averaged" sound level. The L90 is the sound level exceeded 90% of the time and is often considered representative of the background sound level.

"Daytime" refers to the hours between 6 a.m. and 10 p.m. (i.e., 0600 – 2200 hours) "Night time" refers to the hours between 10 p.m. and 6 a.m. (i.e., 2200 – 0600 hours)

Several hours of data at measurement locations M1 and M6 were removed from the October 2007 data set due to apparent equipment malfunction.

Source: Clear Creek Consultants (2007)

Viewpoints were established for evaluating visual contrasts in the Study Area and to document baseline conditions. Factors considered in selecting these viewpoints included angle of observation, number of viewers, duration of view, relative apparent size of the Project, season of use and lighting conditions. The viewpoints were selected to represent locations on roads approaching the Proposed Mining Area from which a person may be expected to view the site features. The two selected viewpoints are located in the communities of New Abirem and Afosu (**Figure 3-13)**. Specific descriptions of these viewpoints are as follows:

- **Viewpoint 1** is located in New Abirem at the intersection of the north-south Nkwakaw road (Inter-regional Road 3) and the road from New Abirem to Adausena (Inter-regional Road 6). The view is to the west toward the Proposed Mining Area as the road disappears over a hill.

- **Viewpoint 2** is located in Afosu on the Nkwakaw road approximately 3.7 kilometres to the north of Viewpoint 1. The view is over a portion of the community to the southwest horizon, toward the Proposed Mining Area.

3.3.3 ACCESS

The Study Area is accessed by turning off the main Accra-Kumasi highway at Nkawkaw and travelling south via Inter-regional Road 3 for approximately 40 kilometres to New Abirem. New Abirem is linked to other towns in the Study Area, such as Mamanso, by a network of un-tarred feeder roads. The road from New Abirem to Adausena is a good GHA road sealed with tar.

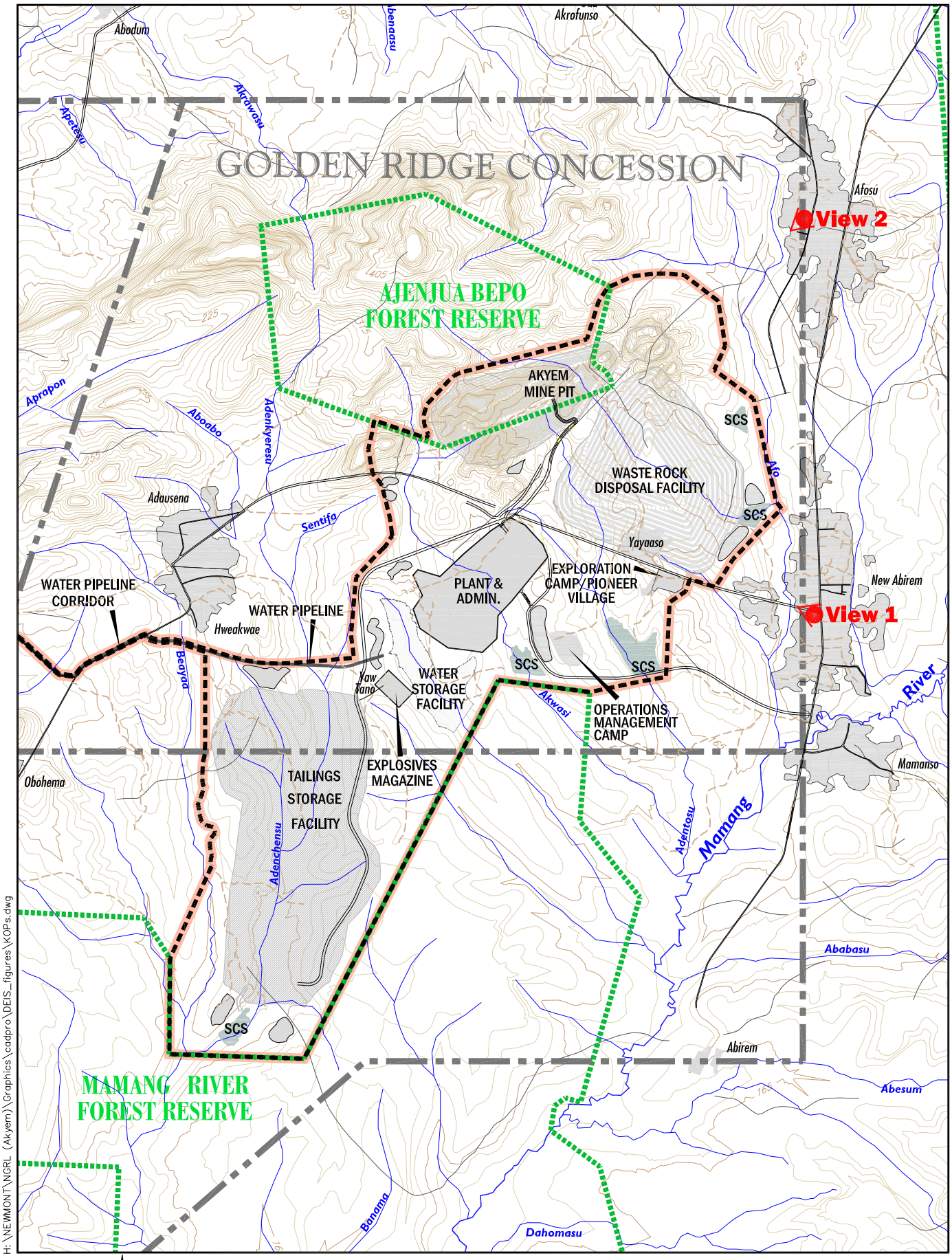
Roads in the Study Area vary from fair to poor. New Abirem and Afosu are situated along the main road from Nkawkaw. The road is tarred and is in fairly good condition, although there are signs of wear and tear and potholes are starting to appear. The main road from New Abirem through the Proposed Mining Area to Ntronang is also tarred and in good condition. Roads within all communities are not tarred and are in poor condition and are susceptible to heavy rains making them impassable in an ordinary car.

There is no public transport system but an extensive private system of buses and taxis provides mobility. Most people seeking goods and supplies resort to walking. Transportation is one of the key hurdles to economic growth in the area expressed by focus groups and some survey respondents.

3.3.4 TRANSPORTATION

The major port of entry for Ghana is Tema, located about 50 kilometres east of Accra. An alternate port in Takoradi is suitable for self-sustaining project vessels and capable of handling heavy and over dimensional cargo.

Transporting equipment to Akyem from either Port would be by articulated trucks with 150 to 250 tonne capacity. The Company has prepared an engineering study of the routes from the Ports of Tema or Takoradi which indicates that the primary routes are in good condition, with some stretches requiring caution to negotiate damaged and uneven surfaces.



Viewpoint Locations
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-13

3.3.5 HERITAGE AND ARCHAEOLOGICAL RESOURCES

The Study Area evaluated for heritage resources study included approximately 190 square kilometres within a 5-kilometre radius of the Proposed Mining Area where direct or indirect effects on the local population could occur. The area evaluated included the communities of New Abirem, Afosu, Ntronang, Mamanso, Old Abirem, Yayaaso, Adausena and Hweakwae and numerous hamlets. Resources surveyed included community sacred sites, individual sacred sites, royal cemeteries, and public cemeteries. To some Ghanaians, it is the spirit at a sacred site or grave that matters rather than the place and that spirit can be moved provided proper rituals are followed and respect given to the event.

Heritage resources within the Study Area were surveyed in March 2008 (Geomatrix Consultants 2008d). Types of data collected were focused on identifying heritage resources in the area in a baseline condition as well as provide information necessary to plan for possible resettlement or relocation of residents, which might require concurrent relocation of certain heritage resources.

Table 3-23 summarizes heritage sites identified in the Study Area. A total of 46 heritage sites were identified of which 18 were attributed by the survey team as "Community Sacred Sites," which serve the community and are overseen by the stool chief, linguist and/or elders. Twelve sites were identified as "Individual Sacred Sites," sites which were located in an individual's home or land and overseen by that individual. Six sites were identified as Royal Cemeteries and 10 were Public Cemeteries.

Of the heritage sites identified, 15 were determined to be within the Proposed Mining Area where planned development of the mine pit, waste rock disposal facilities and other proposed mine features may impact some or all of the sites.

Table 3-23
Summary of Heritage Sites
Akyem Gold Mining Project

Number of Sites	Study Area Total	Inside Proposed Mining Area Boundary
Community Sacred Sites	18	3
Individual Sacred Sites	12	10
Royal Cemeteries	6	1
Public Cemeteries	10	1
TOTAL	46	15

Source: Geomatrix (2008d)

The significance of the sacred sites identified in the Study Area varied although rituals practiced at the different sites seemed to be somewhat similar. Rituals (visiting a sacred site to show respect for or communicate with ancestors) involve libations at a sacred site. The sites identified in the Study Area are often characterized by the presence of a grove or boundary of plants (usually *ntomme* – local name) with sticks and ropes hanging from branches and bottles placed at the base of a tree. The heritage sites are not weeded and branches are not cut. Most commonly, rituals are performed on Akwasidae, the last Sunday in a 40-day cycle, although rituals can be performed when the need arises.

Graves are not scattered around the Study Area but rather confined to identifiable cemeteries. People do not bury in their homesteads, as is the case in many other rural areas in Africa. Two cemeteries have been identified within the Proposed Mining Area at Yayaaso. The larger one is a Public Cemetery, which is currently used and contains about 100 graves. The last burial in the cemetery was reportedly three years ago. The second cemetery is the Royal Mausoleum – last used in 1999.

A Level I Archaeological Survey was performed in the Proposed Mining Area in March 2008 (Geomatrix 2008e). Level I surveys are designed to determine whether or not archaeological sites exist on a particular portion of land. Such work involves checking records of previous archaeological studies conducted in the area, walking over the landscape to inspect land forms and look for surface exposures of soil and possible archaeological material and excavation of shovel test pits in areas of high probability. The study was designed to identify, evaluate and document archaeological (prehistoric and historic) sites, paleontological resources and knowledge-based data of socio-cultural value.

Findings of this Level I study indicate 9 sites are present in the Proposed Mining Area which were determined to be of archaeological significance. Of these, 5 sites were attributed by the archaeological team as being abandoned settlements, 2 were of religious or sacred significance, and 2 were of prehistoric significance. Of the sites identified in the Proposed Mining Area, 6 sites were determined to be within or reasonably close to areas of proposed disturbance where planned development of pits and waste rock disposal facilities could impact the sites. The sites identified within the Proposed Mining Area would require additional study (Level II) before the land can be disturbed to ensure that artefacts have been removed and catalogued appropriately prior to being archived. The Level II study will be performed prior to ground disturbance activities in the Proposed Mining Area.

3.3.6 COMMUNITY HEALTH AND SAFETY

A health baseline study of the Study Area was conducted in early 2006 by International SOS. The principal objective of the survey was to document the health status and challenges that the Study Area population faces. The health survey data serve as a baseline of the health status of the Study Area population at this time and should be used as a reference point for any future comparisons and criticisms that may be made.

The broad objectives of the health baseline survey were:

- Establish a health status baseline for the surrounding communities,
- Understand the knowledge, attitude, perceptions and behaviour of the communities in relation to certain health indicators and conditions,
- Establish the prevalence of important diseases within the affected communities,
- Establish a baseline of heavy metal exposure within the community,
- Provide information of the development of a detailed health risk assessment for potential environmental illness and infectious diseases facing the Project workforce,
- Evaluate potential health risks the Project presents to the community and
- Assist in development of a community health intervention plan and a road map outlining implementation of the plan.

The survey used structured questionnaires and biological samples to obtain quantitative data, and focus group discussions and key informant interviews to obtain qualitative information. A sample of 270 households was selected. Two questionnaires were conducted per household – one for the male household head (when not available, an adult male from the household would substitute) and a female adult. Biological samples were collected from the household.

Principal findings of the survey indicated the following:

- Malaria is the most predominant disease in the Study Area (GRRL 2008b):
  - 29 percent of the children younger than 5 years old sampled for malaria at the time of the survey tested positive for the disease.
  - 65 percent of the respondents knew that the mosquito was the only means of acquiring malaria.
  - 15 percent of households owned an insecticide-treated mosquito net.
  - 29 percent of the children younger than 5 years old slept under an insecticide-treated mosquito net.
  - 18 percent of the children who are younger than 5 years old and had experienced a fever in the 2 weeks prior to the interview were treated with Artemisinin-based combination therapy (ACT) as recommended in the National Malaria Control Programme guidelines (GRRL 2008b).

- The prevalence of HIV/AIDS for the Eastern Region at 4.2 percent rate is the highest in the country (2007 Ghana HIV Sentinel Survey Report). The current HIV/AIDS prevalence rate for the Birim North District is 3 percent based on data obtained from antenatal screening tests conducted in New Abirem in 2006 (GRRL 2008b).

- Other disease conditions include diarrhea, skin, eye, ear and throat infections. Malaria is a water-related insect vector disease, diarrhea is primarily water-borne (fecal-oral) and many skin diseases are water-associated. The incidence of upper respiratory tract infections is associated with living conditions, resulting from the inhalation of smoke from wood stoves in the humid environment.

- Levels of lead found in the sample population in general indicate minimal exposure to possible environmental sources from soil and water. Lead exposure in children younger than 5 indicated a mean average of less than 10 micrograms per decilitre (µg/dL) for all of the sampled communities (10 µg/dL is considered to be a "level of concern" or reference value by the U.S. Center for Disease Control (CDC)). Only 1 percent of the sampled children had lead levels above 20 µg/dL.

- There appears to be no significant exposure to mercury in the general sample population, except for the sample representing artisanal miners. For the artisanal miners, the mean levels of mercury were above the reference value of 20 micrograms per litre (µg/L). In the village of Noyem, 8 percent of the people sampled had values above the reference value.

- A wide degree of variance in arsenic exposure was found in the communities sampled. The overall mean value of 58.35 µg/L was above the reference value of 50 µg/L. The village of Ntronang's levels of arsenic were the highest of the communities, with levels at least 70 percent higher than the next highest community. In some cases, residents from Ntronang had mean arsenic levels that were 4 times higher than other communities. Artisanal miners working in the area had similar levels of arsenic as those in the Ntronang samples.

- While results of lead, mercury and arsenic values in the sampled population indicate some samples above the levels of concern or reference values, dietary factors need to be considered in the evaluation. Reference values are often established in the absence of fish consumption. The sampled population regularly consumes fish and it is estimated that 99 percent of the samples had consumed fish in the 4 days prior to the survey.

- Access to health care for most residents in the Study Area is difficult with the primary health care centre located in New Abirem. Complicated inpatient treatment is available at Holy Cross Family Hospital in Nkawkaw or Saint Dominiques in Akwatia.

- No qualified doctor is available in the Study Area.

- Malnutrition is present in the Study Area and the percentage of children that are underweight (17.3 percent) or wasted (8 percent) correlate with country statistics (GRRL 2008).

- Only 58 percent of children in the Study Area participated in growth monitoring and 42 percent participated in immunization, as reported by both International SOS and Opportunities Industrialization Centers International (OICI) (in GRRL 2008b).

- Illness is common among residents of the Study Area. More than 40 percent of survey respondents reported sickness or injury within their homesteads during the 4-week period preceding the census and socioeconomic survey. Survey respondents indicate that of the members who were sick or injured, 53 percent missed one week of work or school as a result of illness or injury, while another 21 percent lost more than 2 weeks of work or school.

This baseline health information, together with the health impact assessment which was completed in late 2007, would be used to develop a health action plan for the Project.

3.3.7 SOCIAL AND ECONOMIC RESOURCES

This section describes the socioeconomic setting and conditions that shape the Study Area. Social and economic resources include population, demographics, social values and economic activities. The Study Area for social and economic resources is approximately 190 square kilometres in a 5-kilometre radius of the Akyem Gold Mining Project where impacts would have direct and indirect affects on the local population. The Study Area is delineated on the west and northwest by the Pra River from the Asante Akim South District

of the Ashanti Region and by the Mamang River on the southeast and east from the Kwaebibirem District. It stretches about 21 kilometres from the confluence of the Pra and Mamang rivers in the south to the northern boundary and is about 12 kilometres wide from the district capital, New Abirem to the western boundary along the Pra River west of Ntronang. The Study Area includes the settlements of New Abirem, Afosu, Ntronang, Mamanso, Old Abirem, Yayaaso, Adausena, Hweakwae and multiple hamlets and individual farmsteads (**Figure 3-14**). The Proposed Mining Area is as defined previously.

Information presented in this section is extracted from two Social Impact Assessments (SIA) prepared for the Company (CIVA 2005 and GRRL 2008b). GRRL (2008b) includes information from the on-going OICI census, land use and ownership surveys conducted by the Company since 2005, the health impact assessment conducted in 2006 by Newfields and the health baseline study of the Study Area conducted in early 2006 by International SOS, which documents the health status and challenges that the population in the Study Area faces. Both documents contain detailed information, as summarized below. Summaries of the social and economic conditions in the country of Ghana, the Eastern Region and the Birim North District are presented in **Annex C-7**. A description of social and economic conditions in the Study Area follows.

LOCAL SOCIO-ECONOMIC CHARACTERISTICS

An overview of the social and economic conditions in the Study Area and Proposed Mining Area is presented in this section. Brief descriptions of the government and stool structure are provided as well as overviews of the population and demographics of the area and the predominant uses of the land. Information presented herein is presented in CIVA (2005) and GRRL (2008b).

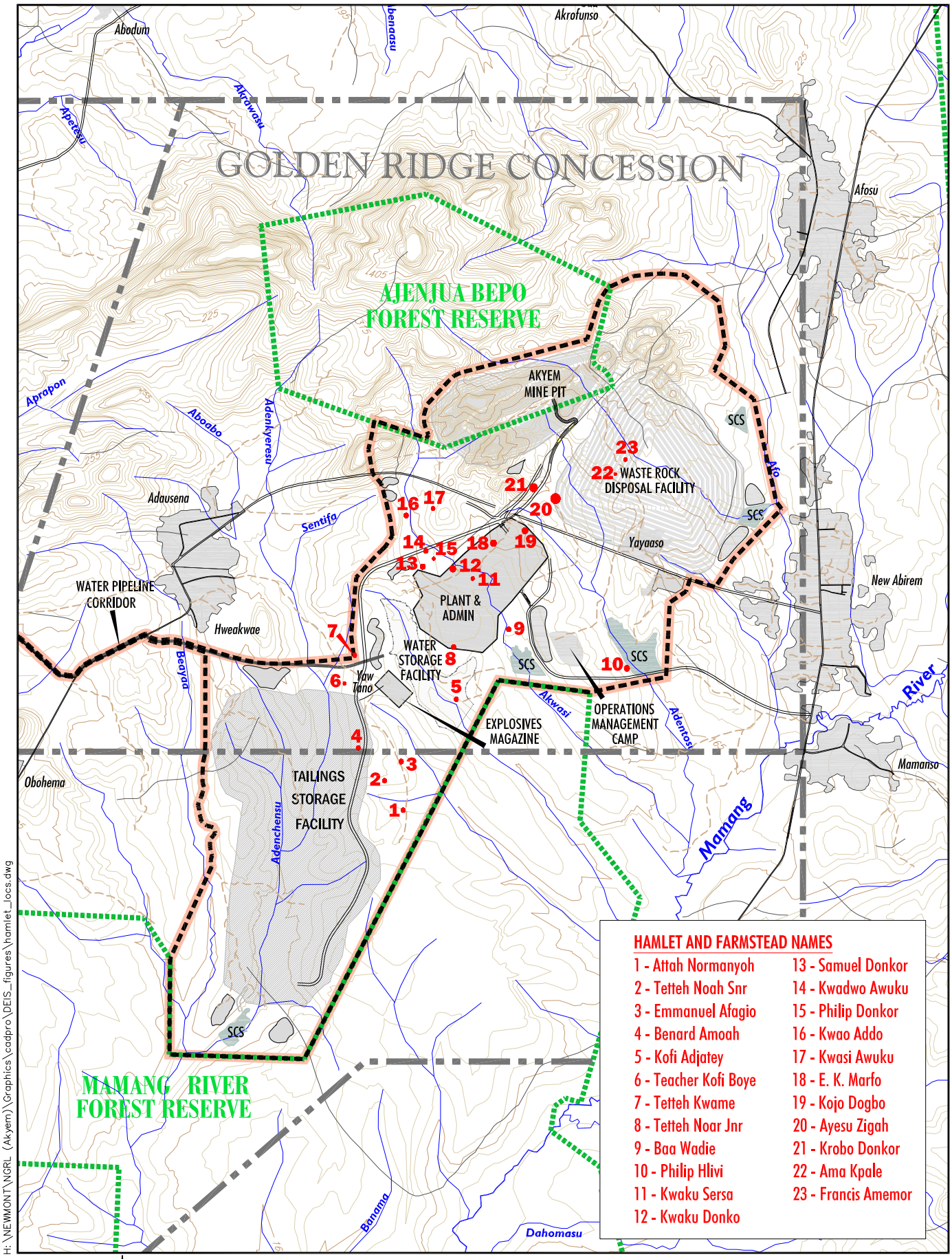
Local Government

The District Chief Executive is the senior Government Official of the District and is appointed by the President of the Republic with approval of two-thirds of Assembly members present and voting. A full description of the administrative and political authority in the District is presented in **Annex C-7**.

Traditional Authority

The Project lies within the Akyem Kotoku Traditional Area with its Paramountcy at Akim Oda. The settlements owe traditional allegiance to the Paramount Chief through the Gyaase division of the Traditional Council.

The Chiefdom consists of the Chief, the Queen mother, sub-chiefs, family/clan heads and a linguist. This gathering is the supreme body in the community and must approve all decisions made. This traditional structure is used to address land allocation, family disputes, town development issues, civil cases and reflects the customs and traditions of the people.



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Hamlet and Farmstead Locations
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE 3-14

Population and Demographics

The 2000 National Census recorded the populations of the 8 settlements within the Study Area ranged from 570 residents in Yayaaso to over 3,500 residents in Afosu. In addition to settlements in the Study Area, there are multiple hamlets and individual farmsteads inhabited by farmers from other regions of the country (**Figure 3-14**). The population of the Study Area is projected to have grown from 15,433 persons in 2000 to 19,418 persons (excluding hamlets and farmsteads) in 2008, as summarized in **Table 3-24**. The 2008 population projections shown on **Table 3-24** were made prior to the 2005 public hearing regarding the proposed Project. Those projections, therefore, may underestimate the 2008 population of Yayaaso and surrounding areas.

According to the household survey conducted in the Study Area during September 2004, 48.3 percent of the studied population is male and 51.7 percent female, almost mirroring the District's figures. The Social Impact Assessment notes that although strict gender-based role differentiation seems to be shifting in the Study Area, many women are still responsible for maintaining the household in a "hands-on" manner on a daily basis. This includes ensuring production (food and water) and reproduction (bringing up children who will participate in subsistence, and possibly income generating, activities in the future).

TABLE 3-24
Estimates of Population in Akyem Gold Mining Project Study Area (2000 & 2008)

Settlement/Hamlet	2000 National Census Population(1)	2008 Population Projection(2)
New Abirem	1,967	3,990
Afosu	3,511	5,325
Mamanso	2,000	2,663
Yayaaso	570	700(3)
Adausena	1,462	1,429
Hweakwae	1,249	1,249
Ntronang	2,732	2,756
Old Abirem	1,411	1,306
Hamlets/farmsteads	531	No projection
Total Study Area	**15,433**	**19,418**

(1) From CIVA (2005).
(2) From Ghana Statistical Service (2002).
(3) 2006 projection from International SOS (2006); no projections available from Ghana Statistical Service.

Approximately 54 percent of the residents in the Study Area are between 16 and 50 years old (27 percent are between 16-30 years of age). This is consistent with national statistics in which the 15-64 age groups makes up 58 percent of the population.

Just more than half (52 percent) of the population is younger than 19, of which 48.6 percent are female. There are 1.6 females and 1.7 males younger than 19 per household. Of the 19-64 age groups, 53 percent are female, and on average there are 1.7 adult females and 1.5 adult males per household. Of the 60+ age group, 58.5 percent are female.

Proposed Mining Area Demographics

The ongoing OICI survey indicates there are 242 households living within the Proposed Mining Area. The total population for the Proposed Mining Area is estimated to be 1,331 persons, with an average household size of 5.5 persons.
Further findings are:

- Approximately 50 percent of the population is female.
- 50 percent of the population is younger than 19.
- 55 percent of survey respondents are native to the area, the other 45 percent moved from elsewhere in the country to settle in the area to farm.
  - The majority of migrants come from the other parts of Eastern Region, as well as from the Ashanti, Central, Brong Ahafo, Northern and Volta regions.
  - 16 percent of migrants have been resident in the area for more than 25 years.
- The population's religious beliefs can be divided as follows:
  - 84 percent Christian
  - 14 percent traditional religion
  - 2 percent other religions

The Health Assessment found that the main cause of morbidity in the Proposed Mining Area is malaria, which makes up 82 percent of illnesses reported. Other disease conditions include diarrhea; as well as skin, eye, ear and throat infections.

Land Use

The primary land use in the Proposed Mining Area is agriculture (**Figure 3-2**). As of March 2008, the Company had identified 2,734 farms within the Proposed Mining Area. There are 242 households (1,331 persons) present within the Proposed Mining Area (residents). An additional, 1,443 households (7,937 persons) are located outside the Proposed Mining Area but have farms within the Proposed Mining Area (non-residents). The Proposed Mining Area supports 1,685 households on an average farm size of 0.9 hectares. Descriptions of the land tenure arrangements in the Study Area as well as more detailed descriptions of the land uses are included in **Annex C-7**.

Settlement Descriptions

The primary settlements located within a 5-kilometre radius of the Proposed Mining Area are shown on **Figure 3-1** and include Afosu, New Abirem, Mamanso, Old Abirem, Adausena, Hweakwae and Ntronang. In addition, several hamlets and individual farmsteads are present throughout this area. Descriptions of the social and economic characteristics of these settlements and hamlets are included in **Annex C-7**.

The primary settlement in the Proposed Mining Area is Yayaaso (**Figure 3-1**). The settlement is still regarded as a settler community because the inhabitants are predominantly non-Akyem. The estimated population in 2000 was 570 occupying 100

houses. Using the 2000 Census figures, the International SOS (2006) Health Survey estimated Yayaaso's population in 2006 at 700 persons. The initial Social Impact Assessment noted that Yayaaso is a very poor village for the Study Area with a striking feature of the settlement being the poor construction of most of the dwellings. This has been confirmed by the OICI survey that reports that 62 percent of respondent households had built their houses with mud or mud bricks, while a further 7 percent live in houses built with baked bricks and 28 percent of the respondents live in houses built with cement or sandcrete blocks. Seventy-three percent are reported as having roofed their houses with corrugated metal sheets.

The settlement is served by a piped water supply. A 120 cubic metre tank, which forms part of the water system, is located at Yayaaso and also provides water to Afosu, New Abirem and Mamanso. Yayaaso has two public water standpipes, one borehole and one hand dug well. The community has one public pit latrine and one dumping site neither of which is actively managed. The village has limited access to electricity and has one operating streetlight.

According to the Social Impact Assessment, common illnesses in the village include malaria, occasional flu-like fevers, waist pains, piles, stomach aches, skin irritation, hernia, diarrhea and epilepsy. Although Yayaaso has a health volunteer, there is no health facility in the village and the people travel to New Abirem (2 kilometres away) to seek medical attention.

The people of Yayaaso are mainly farmers engaged in the cultivation of cocoa, oil palm, citrus, maize, cassava, plantain and cocoyam. Production of cocoa ranges between ½ bag and 30 bags from farms between 0.2 to 6 hectares in size. Food crop farms range from between 0.2 to 1.2 hectares; the two most important food crops are cassava and plantain.

The settlement has 4 masons, 2 carpenters, 2 mechanics, 2 electricians, 4 seamstresses and 2 tailors. There are 4 stores, 7 drinking spots, and 2 hair salons in Yayaaso. There is no chemical store, entertainment spot, community centre nor palace. Of greatest economic value in the community is the presence of 2 oil palm processing facilities and 3 corn mills. The settlement has a primary school and 2 churches.

Hamlet and Farmstead Description

Hamlets and individual farmsteads located within the Proposed Mining Area are shown on **Figure 3-14**. The buildings are structurally poor and are generally of wattle and daub construction with rammed earth floors and thatched or bamboo roofing with a few buildings having corrugated iron roofing sheets. There are no public facilities or services in these hamlets, and economic activity is limited to agricultural pursuits. To access these facilities, the inhabitants travel to Adausena, Hweakwae, New Abirem or Nkawkaw. Most of the residents of these hamlets raise cash crops of cocoa, oil palm and citrus and grow a variety of food crops including cassava, pineapple, cocoyam, plantain, maize, ginger and vegetables.

Residents rely on streams, and hand dug wells or shallow pits as sources of drinking water. Residents use pit latrines and dispose of garbage in various places. Common diseases among residents in the Study Area include malaria, piles, waist pains and rheumatism.

Residents in the Study Area belong to one or more identifiable communities or social groups, including religious and cultural groups and youth development associations. Many have friends in nearby homesteads where they can seek assistance such as counselling and loans and obtain water, fuel and farm inputs.

INFRASTRUCTURE

Spread among the settlements in the Study Area are 18 kindergartens, 23 primary schools (catering to children aged 1 to 6) and 15 junior high schools (ages 14 to 16). There are no vocational training facilities. There is limited access to health care for most residents in the Study Area. The main facility in the area is the New Abirem Clinic, which was recently renovated and is currently being upgraded. The International SOS survey, as cited in GRRL (2008b), found that in 2005, 93.7 percent of the respondents interviewed in the Study Area had access to an improved drinking water source, either through a public tap (54.4 percent) or a protected well (38.9 percent). The International SOS survey, also found that in 2005, 89 percent of the surveyed population in the Study Area had access to toilet facilities and that 66 percent the respondents interviewed disposed of their household waste on the communal dump.

Under the Self Help Electrification Project, electricity has been extended to all settlements in the Study Area and Yaw Tano, the largest of the hamlets in the Proposed Mining Area. In addition, a government post office and some commercial telephones are located in New Abirem. Yayaaso, Adausena and Hweakwa have some fixed telephone lines (GRRL 2008b). All the Study Area communities have access to a mobile telephone network. Police and fire-fighting infrastructure is limited in the Study Area. **Annex C-7** provides summary descriptions of the infrastructure in the area, including that for education, health care, water supply, sanitation, solid waste disposal, electricity, communication systems and safety and security.

EMPLOYMENT

Household livelihood strategies in the Study Area are described as an ongoing process of balancing the need to generate cash to pay rent and school fees and to purchase household and personal items and the need to produce food for personal consumption and sale. As summarized in **Table 3-25**, agriculture is by far the most common occupation in the Study Area**.**

TABLE 3-25
Summary of Employment Status (2004)

Status	No. of Responses	Percent
Farmer	180	64
Self-employed (petty trading, technicians, and artisans)	48	17
Salaried	34	12
Unemployed	5	2
Retired	2	1
Not working (elderly)	11	4
Total	**280**	**100**

Source: CIVA (2005) Household Survey

Livelihood activities overlap within the Study Area and are used with one another to increase family strengths and survival mechanisms. Most residents work on farms, in addition to their self-employment or salaried jobs. The primary livelihood categories are presented below:

- Agriculture and natural resource use
  - For family consumption
  - For cash sale (surplus food/cash crops, commercial, production through GOPDC, market sales) and
  - From ethnobotanical and commercial use of forest reserve resources

- Self employment
  - Through individual market sales of produce and
  - Through labour (carpenters, hairdressers, dressmakers, fabric tie and dye artisans, masons)

- Salaried work (teachers, health workers, civil servants, mine employees) and

- Other strategies to secure livelihoods and obtain care (remittances, rent, pensions, marriage and cohabitation)

Agriculture and Natural Resource Use

As indicated above, farming is the primary occupation of people in the Proposed Mining Area. Although cocoa was the most important cash crop in the past, it has given way to oil palm and citrus. Oil palm is now the leading cash crop in the area. Food crops such as plantain, cocoyam, cassava and maize are planted as intercrops in the young tree crops of oil palm and citrus. In some areas, food crops have been established for subsistence; these are prominent around settlements and hamlets.

The main agricultural system employs traditional inputs, namely land, family labour and simple tools and equipment. The majority of farmers rely on their own stock for planting materials and the natural fertility of the land for production. Farming is labour intensive, not mechanized and agro-chemicals are seldom applied. The farmers seldom employ additional labour for farm work. As a result, most food crop farms are generally small averaging less than a hectare and thus surpluses for the market are meagre.

Most farmers practice mixed food crop farming on a land rotation system. The system employs slash and burn and zero-tillage techniques for land preparation. Farmers rotate farmland to allow some fields to lie fallow (abandoned or unused). After burning, plots are typically farmed and harvested for two years before being left fallow. Secondary burning and cultivation usually occurs 5 to 10 years after the plot has been abandoned. Further discussion of these activities is included in **Annex C-7**.

Small-Scale Trading and Self Employment

Apart from small-scale agriculture, there are a number of small-scale industrial establishments, which can be classified as:

- Agro based -- garri processing and oil palm extraction,
- Wood based -- saw mills,

- Clay based -- pottery, and
- Textile based -- tie and dye, dressmaking.

A survey conducted by the District Assembly in 2002 indicated that 19.4 percent of the labour force is engaged in commerce, trading in items such as provisions, food stuff, agricultural produce, alcohol, crafts, cloths and textiles and hardware.

Seventeen percent of the respondents to the initial SIA household survey classified themselves as involved in small-scale trading, primarily through market sales of produce, or self employed as carpenters, hairdressers, dressmakers, tie dyers, or masons. When reviewing the community thumbnail sketches presented in the land use section, it is clear that there are few retail opportunities and many small-scale traders do not have store-front shops. There are markets in New Abirem and Ntronang. There is no designated market in the Proposed Mining Area.

Salaried Work

Twelve percent of the respondents to the initial SIA household survey were employed in salaried positions, including teachers, health workers and civil servants. New Abirem is the district capital with jobs there associated with government functions.

Galamsey Mining

'Galamsey' (illegal artisanal mining) is an important non-farm income generating activity in the Birim North District. In mid-2004, galamsey mining activities began at Noyem, Nyamfoman and Akoasi, approximately 5 to 10 kilometres northeast of Afosu. By the end of the year, an estimated 1,000 people were mining and living on the concession. In 2005 and 2006, Government authorities engaged in actions to remove the small-scale miners from the area as their activities are illegal and destructive to the local environment; however, a significant level of activity continues. Galamsey activity is also occurring at the old Kenbert mine outside of Ntronang, approximately 5 kilometres to the west of the Proposed Mining Area.

Other Categories

Approximately 5 percent of the 280 heads of households surveyed during the initial SIA were retired and perhaps receiving a pension or did not work because they were elderly. The SIA interviews did not identify use of marriage and cohabitation.

UNEMPLOYMENT

According the initial SIA survey, 2 percent of the population in the Study Area indicated that they are unemployed. Limited formal economic activities, together with only small-scale markets in some settlements, suggests restricted economic activity for residents.

SOURCES OF INCOME AND EXPENDITURE

The main rural economic activity in the Study Area is food and cash crop farming (**Table 3-26**). Estimated annual income of households surveyed ranges from 37.26 GH¢ (36.90 USD) annually to 4,057.74 GH¢ (4,159.14 USD). Zero income was reported by six households.

TABLE 3-26
Summary of Primary Sources of Income
Akyem Study Area

Activity	No. of Respondents	Percent of Respondents
Agriculture	210	75
Trading	26	9
Salaries	22	8
Remittances	14	5
Pensions	2	1
Rent	1	<1
Others	5	2
Total	**280**	**100**

Source: CIVA (2005)

Respondents to the SIA household survey were asked to indicate items that had an effect on their expenditures in the past 12 months. The findings reveal that the inhabitants' major expenditures are for food, education and health indicating that people spend their income on basic needs, in addition to hiring of labour on their farms. Of 280 households, 120 (43 percent) named food as having a very strong claim on their income (**Table 3-27**).

TABLE 3-27
Communities Primary Claim on Income
Akyem Study Area

Category	Number of Respondents	Percent of Total Respondents
Food	120	43
Education	84	30
Hiring of labor	38	13
Health	27	10
Clothes	3	1
Funerals	3	1
Agricultural Inputs	2	1
Building Project	2	1
Bills	1	<1
Total	**280**	**100**

Source: CIVA (2005)

One concern expressed by health workers at the New Abirem Centre was the increase of accommodation costs as a result of the Project presence. Rates for accommodations have risen from the range of GH¢1 per month to GH¢2 per month for a single room to GH¢5 per month. The increased monthly rate, combined with a typical 3 month deposit required up-front, makes it difficult for non-mine employees to afford rental accommodations (GRRL 2008b).

Retail Prices

The Ministry of Food and Agriculture (MOFA) collects wholesale and retail prices each year. **Table 3-28** presents a sample of the annual averages for a variety of vegetables, fruits and protein products for the Akoase market. Prices for grains were steady from 2006 to 2007 with a decrease in the retail price of maize. Prices for vegetables increased overall with a relatively large increase in the retail price of cassava (300%). The retail price of pineapple decreased 100 percent. Retail prices for protein sources were variable with a 200 percent increase in the price of pork and a 56 percent decrease in the price of beef.

No pattern of inflation is evident between 2006 and 2007 for the Birim North District. Rather, prices appear to be caused by local supply and demand issues based on seasonal availability. Preliminary data for 2008 indicate significant increases in food prices in Akoase.

TABLE 3-28
Retail Price Comparison at Akoase Market
Akyem Gold Mining Project

Commodity	Unit of Sale	2006 Retail Price (GH¢)	2007 Retail Price (GH¢)	Change 2006 to 2007 (GH¢)	Change 2006 to 2007 (percent)
Maize	1 kg	0.60	0.35	-0.25	-42
Millet	1 kg	--	--	--	--
Guinea Corn	1 kg	--	--	--	--
Rice – local	1 kg	--	--	--	--
Rice – imported	1 kg	0.80	0.84	0.04	+5
Yam – white	1 kg	0.50	0.90	0.40	+80
Cocoyam	1 kg	0.30	0.40	0.10	+33
Cassava	1 kg	0.10	0.40	0.30	+300
Garri	1 kg	0.40	0.40	0.00	0
Cassava Chips (kokonte)	1 kg	0.20	0.50	0.30	+150
Plaintain – Apentu	1 kg	0.40	0.50	0.10	+25
Orange	1 kg	0.15	0.20	0.05	+33
Banana	1 kg	0.60	0.20	-0.40	-67
Pineapple	1 kg	0.40	--	--	--
Mangoes	1 kg	--	--	--	--
Tomatoes	1 kg	0.60	1.20	0.60	+100
Garden Eggs	1 kg	0.30	0.30	0.00	0
Onion	1 kg	0.80	0.70	-0.10	-13
Ginger	1 kg	0.30	0.30	0.00	0
Dried Pepper	1 kg	6.00	0.70	-5.30	-88
Unshelled Ground Nuts	1 kg	--	--	--	--
Groundnuts – red	1 kg	1.00	1.00	0.00	0
Cowpea	1 kg	0.70	0.90	0.20	+29
Groundnut Oil	1 kg	--	--	--	--
Palm Oil	1 kg	0.52	0.64	0.12	+23
Beef	1 kg	3.60	1.60	2.00	-56
Pork	1 kg	1.20	3.60	2.40	+200
Smoked Herring	1 kg	2.20	3.50	1.30	+59
Salt Dried Fish (kobi)	1 kg	3.00	3.00	0.00	0
Eggs – commercial	single	0.10	0.12	0.02	+20

Source: Ministry of Food and Agriculture Statistics, Research and Information Directorate.

Other Information

In the 2005 OICI survey, households interviewed indicated that they sold part of their food crops for the following reasons:

- 83 percent for staples and non-personally grown food purchases,
- 46 percent for agricultural inputs purchases,
- 29 percent for clothes purchases,
- 24 percent for funeral expenses,
- 23 percent for education expenses,
- 18 percent for medical expenses and
- 20 percent for personal reasons.

VULNERABLE POPULATIONS

The Fourth Ghana Living Standards Survey (GLSS 4) defines "extremely poor" as those whose living standard is not sufficient to meet their nutritional requirements, even if they devote their entire consumption budget to food. On a national basis, GLSS 4 and various participatory poverty assessments have identified the following groups as including the extremely poor, the vulnerable and the excluded:

- Rural agricultural producers, especially migrant workers and sharecroppers,
- Children in difficult circumstances,
- Persons living with HIV/AIDS,
- Displaced communities, including communities affected by mining,
- Disadvantaged women, particularly single mothers,
- The elderly,
- Physically challenged persons,
- Persons suffering from chronic debilitating disease,
- Drug addicts,
- Victims of abuse and harmful traditional practices and
- Unemployed, especially unskilled retrenched workers and the unemployed youth.

The Company has instituted a "vulnerable" register to ensure all vulnerable people in the Proposed Mining Area are identified and tracked during the resettlement process.

HOUSEHOLD ASSETS

A household's quality of life depends on access to basic social infrastructure and services. Thus, the lack of access to resources such as health and educational facilities, as well as ownership of material goods, is a useful indicator of poverty and the vulnerability of a group of people.

The OICI survey reported that in 2005, 62 percent of respondent households had built their houses with mud or mud bricks, while over 73 percent roofed their houses with corrugated metal sheets. Twenty-eight (28) percent of the respondents live in houses built with cement or sandcrete blocks, while 7 percent live in houses built with baked bricks. The respondents indicated that:

- 57 percent own the dwelling they live in,
- 12 percent pay rent,
- 30 percent use the dwelling without paying, and
- 0.3 percent live in a temporary dwelling.

The OICI survey reported that the respondent households in the Study Area have the following assets (costs not available):

- 82 percent own radios,
- 34 percent own television sets,
- 29 percent own electric irons,
- 26 percent own refrigerators,
- 88 percent own mattresses or beds,
- 67 percent own clocks or watches,
- 5 percent own a car or a truck,
- 4 percent own motorcycles and
- 41 percent own bicycles.

ECONOMY

Households in the Proposed Mining Area generally engage in the cultivation of food and cash crops. The OICI survey reports that almost all households cultivate farms. Agricultural production is limited by inefficient farming practices, lack of tools and equipment, lack of critical inputs and poor soil fertility. The farmers also experience high post-harvest losses. Typically, incomes are low due to the small farming area, limited non-farm income generating opportunities and poor transport infrastructure. Crops are generally sold to traders or to markets in New Abirem and Ntronang. One-hundred and seventy-four (174) farmers in the Proposed Mining Area are identified as out-growers for Ghana Oil Palm Development Company. Limited livestock are kept, primarily to supplement household income.

The Social Impact Assessment survey reported that Yayaaso was the second highest employer of labour in the Study Area. Non-farm income sources include petty trading, food processing, tailoring/sewing, artisans, rent of buildings and land, pensions, dividends from group investments and rent of farming equipment. The list below presents the types of businesses found in the Proposed Mining Area.

- Drinking bars (2),
- Kiosks (12),
- Oil palm processing facility (2),
- Corn mills (2),
- Carpentry shops (4) and
- Marketing shed (1).