GABON Roads and Reduced Impact Logging (RIL) Efforts
Observations/Comments
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Introduction

During the period of February 2 until February 11, 2005, Gordon Keller, Geotechnical Engineer with the USDA Forest Service, worked with Mans Vroom consultant with FORM International and the Tropical Forestry Foundation to evaluate the roads component of the Reduced Impact Logging (RIL) program in Gabon, West Africa. Part of the time was spent in Libreville, Capitol of Gabon, and 6 of the days were spent in the field near Lastoursville at the SBL logging operations in Eastern Gabon. The purpose of the trip was to evaluate the road conditions in the area, the road activities being undertaken by SBL, and to assist the RIL program with road improvement measures where possible.

The contents of this report (below) document those observations, findings, and recommendations for road improvements. Basically there are many road improvements that should be made, both to be more cost-effective, and to provide better environmental protection in the operation. There are both technical challenges to building better roads, as well as institutional issues to be overcome. The technical aspects are generally discussed in this report. However, a variety of "institutional" must also be dealt with to produce good roads in this region. They include:

- Difficulty to get supplies and fuel in this region;
- Lack of trained personnel;
- Remoteness of the area, making progress slow and, at times, difficult;
- Heavy rains, clay soils, and locally steep terrain;
- People used to road construction "the old way";
- Lack of supervision and inspection;
- Lack of appropriate road construction equipment;
- Logging company cash-flow problems; and
- Lack of operational planning.

Despite the many obstacles to good road construction in this country, the efforts of Mr. Vroom to date are paying off and some improved road construction activity was seen. He is also quite enthusiastic about the improved road work and is working hard to make it happen. SBL, the cooperating logging company, also seems quite supportive of the RIL concept and working towards road improvements. Their ability to implement the work rapidly is hindered, however, by current company cash-flow problems because of non-payment to date on several shipments of their lumber. Hopefully this is only a short-term problem.

General Forest Roads

The two key issues that are most obvious when looking at newly constructed roads and old existing roads are the excessively wide roads with major ground disturbance and the lack of surface drainage. The road traveled way, even for local roads, is typically 7 to 9 meters wide, with an additional clearing width of 10 to 15 meters on each side of the road. Also there is an acute lack of road surface cross-drainage, with water running down roadway ditches for hundreds of meters, particularly on long steep sections of roads.

There is a general lack of regard for the cost of road construction, thus being inefficient with excessive work and the wrong type of equipment for some jobs. Most work done is with a small cat, with no grader to slope back cuts, no compaction equipment for loose fills, no backhoe to facilitate cutting small relief drains, or no loader and dump trucks to haul pit run laterite for local rock reinforcement. A water truck may not be needed in this wet climate.

Given how much emphasis is placed upon **cost** of operations, short-term cash flow concerns, and short-term profitability, RIL road activities need to be considered in two categories. They are **1) top priority** work for cheap but effective (immediately cost-effective) road improvement measures, including:

- better defined road standards with specific minimum road and clearing widths, curve radii, etc. to reduce construction costs;
- better road location to avoid reconstruction needs;
- improved road surface drainage and more frequent cross-drains, as well as installation of drainage structures such a rolling dips, log culverts, of log bridges in drainage where needed; and
- additional use of road aggregate surfacing (laterite rock or other pit-run material) in poorly drained or clay-rich sections, or steep sections of road where traction is needed.

2) Second priority issues are long-term cost-effective or environmentally desirable (as well as from road function) measures including:

- proper sizing of drainage structures (bridges and culverts) to achieve a useful "design life", such a 10 to 20 years;
- addition of armoring in ditches and on the road surface to prevent erosion and extend the haul season or minimize delays after periods of rain;
- using flatter cut (1:1 or so) and fill slopes (2:1 or so), in conjunction with erosion control measures, to achieve long-term stable slopes that minimize slumping and failures that require maintenance or repairs;
- erosion control measures to cover disturbed or barren areas and control drainage to prevent sheet erosion and the formation of rills and gullies;
- development of quarry and borrow area management plans and site reclamation plans to control use of the area, minimize area impacts, and leave the area in a relatively useful condition;
- closing roads and developing of a road management strategy to limit access to the area, thus protecting the area and minimizing problems from illegal occupancy, illegal logging, poaching, and bushmeat hunting; and
- use of Streamside Management Zones (SMZs) to limit disturbance in the live streams and riparian areas along drainages.

Also consider that road building is a **process**, with a number of important steps, or considerations. Each part is important to produce a functioning, long-lasting road, and to reduce the initial and ongoing costs of roads. Without each part a road will not work or will be less useful or more costly than necessary. Steps include the following:

- A road needs **Planning**, good **Location**, proper **Design**, quality **Construction**, and **Maintenance**.
- To build and maintain a good road, you need skilled, experienced, properly trained **people** (as well as technical resources).
- Road builders need the proper equipment for the job, including a Cat, Grader, Backhoe, and Dump Truck (and ideally also a Loader, Compactor, and Water Truck).
- Good construction requires inspection and construction supervision, Plans and Specifications, and occasionally some Quality Control, Sampling and Testing.
- Any road needs ongoing maintenance with a maintenance plan and a source of funding to accomplish the work. A well built road will reduce maintenance needs and costs, but eventually the road still needs maintenance!

<u>Appropriate Road Classification and Standards</u>

The appropriate type of road, or standard of road for the anticipated use, is needed to achieve a suitable balance between cost of the road, ease of use and safety for the road user, and use of resources and impact on the environment. A high standard road is expensive, relatively wide and impacts a relatively large area, uses considerable resources, but servers a large number of people and moves them quickly and safely. A low volume road, such as a local logging road, should be narrow, impacting a relatively small area, use a winding alignment conforming to the topography and minimizing earthwork, it may be used only briefly, and it should be relatively inexpensive. Thus each is cost-effective for its use and impacts.

The road classification used in this region of the Congo by SBL appears appropriate and typical, with Access Roads, Principal Roads, Secondary Roads, and Side Tracks, or local roads. Additionally unimproved skid trails are used to haul logs where cut out of the woods and to the landings.

Access Roads (Arterial Roads or National Roads)- These roads connect national areas and towns to the principal logging centers.

Principal Roads (Collector Roads)- These roads are the highest standard road within a management area and connect the jungle with the towns. They are usually kept open to access a number of management units.

Secondary Roads – These roads access specific management units and connect them with the collector road system.

Side Tracks (Local Roads)- These roads are the lowest standard road within a cut area and provide log haul with trucks from individual landing areas to the secondary road system.

Design standards from Principal Roads to Side Tracks typically vary from road widths of 6 -7 meters to 3.5 to 4 meters; curve radius of 25 meters to 15 meters; aggregate surfacing to no surfacing, etc, respectively. The Table below shows a common range of road standards used with Forest Roads as a function of road classification.

Design Parameter	Principal Road	Secondary Road	Side Track	*Local SBL Roads
Road Width	**6-7 m.**		**3.5-4 m.**	**7-9 m.**
Min. Curve Radius	**25 m**		**15 m.**	**20-25? m.**
Surfacing Type	**Aggregate**		**Native Soil**	**Native + Laterite**
Clearing Width	**3 m.**		**1 m.**	**10- 15 m..**
Surface Drainage	**Ditches and Culverts**		**Rolling Dips**	**Some ditches and lead-offs**
Maximum Grade	**12%**		**18%**	**20%**

*** Based upon observation of a number of local SBL logging roads.**

Note that a significant feature of the logging roads being constructed in Gabon by SBL is that little width variation exists between the Principal Roads and the Side Tracks. Overall the standards are quite similar, implying that the lower standard roads are considerably overbuilt for their intended use and period of haul. More funds could be put into quality main haul roads or for control of their use, while less funds could be spent on lower standard roads.

<u>Excessive Road Width</u>
Major amounts of ground disturbance on new forest roads because of excessive width (6 to 8 meter road width plus additional 6 to 12 meter clearing width), with the idea that clearing is needed for sunlight to get to road to dry it, and use of a Cat for felling trees rather than chainsaw cutting trees in the clearing areas. Width may be appropriate for all year use main collector roads, but excessive width for local access roads that will be used for a couple weeks every 25 years.

Questions? How necessary is the additional clearing to allow sunlight to dry out the roads? How much more quickly does it dry with the opening and more sunlight? On main haul roads, it appears very desirable. On local roads it is not necessary IF log haul can be controlled and wait till the road dries.

The access road into the planned camp near IMENO was constructed by the old Cat operator with a road width of 8 to 9 meters, and an additional clearing width of about 15 meters on each side of the road. Thus the full cleared width is about 40 meters wide.

<u>Road Location</u>
The old ridgetop road system appears well located, with a minimum of steep grades. Some new roads have excessively steep grades (16 to 20 %), with no mitigations such as surfacing or adequate cross drainage.

One new road was constructed with a 20 % grade, and a newer 600 meter long bypass road was being constructed with less steep grades to solve the problem. Unfortunately the original road could have been located with flatter grades with better initial road location. Second, once constructed, the first road may have been suitable considering that it will only be used for a couple weeks of haul. Additionally the cost of mitigations such as waiting to haul when dry or importing surfacing for the steep pitch would likely have been less costly than the construction of the bypass.

A similar bypass road was built in the IMENO area to avoid a steep grade and sharp curve. The new road was built with a better alignment but still has grades of 19%. Prior to building the bypass, the cost of improving the original alignment should have been considered, as well as a couple improved alignments.

Road Surface Drainage

Downcutting is occurring in the inside ditches and occasionally in the road surface in numerous areas due to concentrated water running down the road and lack of lateral drainage (cross- drains) to disperse the water. Additionally this concentrated water with accelerated flow velocities is causing gully erosion once it leaves the road.

From a **purely economic standpoint**, there are several principal reasons for having good road surface drainage. They are:

- To reduce the need and frequency of maintenance and repairs on the road;
- To reduce aggregate loss from the roadway surface where surfacing has been applied;
- To increase haul speed and reduce haul time, thus saving money with reduced haul costs; and
- To reduce damage and wear on vehicles.

Obviously the other principal reason for good drainage is to decrease erosion and sedimentation problems, but this is an adverse environmental impact and an indirect, long-term economic factor under some conditions.

Road surface drainage can be achieved either with better defined road crowns, insloping, or outsloping, and ditch relief can be achieved either with rolling dips or culvert cross-drains. Some of the recently graded main collector roads, particularly the access into Area 21, do have a well shaped crown and good surface drainage. On National Road 6 (NR6) to Inemo Plateau, lack of maintenance and surfacing material, which has produced more rutting, has left the surface rough with much poorer drainage and concentrated water flow.
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On local or secondary roads, with relatively low driver velocities and road grades less than 8 to 10 %, use of rolling dips, or “broad-based” dips would be very cost effective, both to remove the ditch water as well as drain the roadway surface. On the higher speed, collector roads or national roads, the ditch relief (drainage) is usually achieved with a series of cross-drain culverts with inlet basins. Spacing of either the dips or culverts is commonly 30 to 150 meters, depending on road grade and soil type. Actual on-the-ground spacing will depend on local breaks in the road grade and logical locations to disperse (exit) the water.

Surface Armoring with Quarry/Pit Run Material (Laterite)

Armoring of a roadway surface with **laterite**, gravel, pit run rock, crushed aggregate, or pavements are all desirable for a variety of reasons. It increases the design speed of the road, user comfort, it prevents or minimizes sediment production from the road, and it physically makes the road passable in clay-rich soil areas. For logging road applications in this region, it is very important on the main collector roads to provide an all-weather surface, year around, or multi-year use of the road. On secondary or local roads "spot-rocking" (local application of rock) is very desirable where wet season haul is desired, to speed up use of the road after rains, to pass local wet and clay-rich areas, and to provide traction on steep road grades (over 8-10%). Commonly an application of 3 to 6 cm of laterite is adequate on a road surface. In soft, wet, clay rich areas with heavy traffic, the area may need to be dug out to a meter or more depth and backfilled with coarse rock or laterite.

Fortunately much of the region is covered with deposits of laterite (a gravelly-rocky hard concretion in the soil profile). It is commonly spread across the region and can offer a natural gravel armoring to the road surface. Also some deposits of the laterite are locally deep and extensive, making excellent borrow pit sites.

To facilitate road construction, maintenance, and repairs, as well as to spot rock" local soft areas, a loader or tractor and dump truck are needed to load the laterite from a pit and haul it to the area needing reinforcement. Without this equipment it is difficult to construct or maintain a suitable haul road. The alternative is to limit road use to dry periods.

Materials Source Management

Some advantages can be realized by doing more materials source location, investigation to determine the quantity and quality of material available, and economic analysis of the haul and use costs. Advantages of materials source investigation include better quality control, better project planning, and occasional closer and cheaper sources of materials. For a large road construction program such investigations can be very cost-effective, but for small operations the benefits may be marginal. Sharing resources with other local road building agencies or projects may be a good solution.

Finally, if materials sources are developed and used (their use is certainly strongly encouraged), some consideration should be given to site reclamation when use is finished. Basic considerations include site safety, future use, drainage, and erosion control. In sensitive areas, materials source planning and reclamation can avoid impacts on wildlife, sensitive plants, or archaeology features, visual problems, and water quality degradation. In most non-sensitive areas concerns are principally for desirable future use of the area and local safety.

Roadside borrow areas are occasionally used, but the widely distributed laterite deposits throughout the region minimize their need. However, in areas without laterite, designated quarries and roadside borrow areas have been occasionally developed and used. Use of local materials sources can represent a major cost savings to any project since the cost of surfacing material (aggregate or pavement) can often be one half of the cost of the road.

The **advantages** of local or roadside materials sources are their convenience and the major cost savings realized by avoiding long transportation costs. The **disadvantages** of local materials sources are their often limited volume of useable material and variable or marginal quality material. Other disadvantages may include visual impacts or lack of consideration for other environmental impacts. Often the tradeoff of using local materials is lower quality material which is initially inexpensive, but difficult or expensive to maintain. Alternatively a higher quality material is often more expensive to locate and produce, and haul to the road, but requires less maintenance and it lasts on the road longer without potholes, washboarding, etc.

Alternative Surfacing Materials

On local and temporary use roads an alternative style of local road subgrade stabilization is the use of logs or organic matter to form a **"corduroy"** road. Basically the road is supported by "floating" the roadway across a wet or soft area on a series of closely spaced logs set parallel to each other, transverse to the direction of the road. Log diameter has varied from 10 to 30 cm, but should be a fairly uniform size in any given area. The logs are then usually capped with a layer of soil or aggregate 10 to 15 cm thick. Corduroy roads and landing areas have been used quite successfully in a wide variety of settings. Most logs are left in place to rot, while others have been removed after haul, washed, and reused or chipped.

Other attempts to provide low-cost access across soft soils and wet areas have included "hardening" the surface with logging slash, sawdust or wood chips ("chunkwood"). Each has worked successfully to varying degrees, and each only for limited use roads. Coarse slash helps support traffic but will punch into the soil and can damage vehicles or tires if not covered with soil. Sawdust is rather fine and deteriorates rapidly, can dust when dry, compresses, but does improve trafficability with a moderately thick layer. Other wood products such as wood pallets or wood mats (or even tire mats), often separated with geotextiles, have been used with varying degrees of success, but typically only in very localized areas.

Coarse wood chips or "chunkwood" has been the most effective to improve road performance. It has also aided in surface erosion control and to reduce dust. Chips have commonly been of a 5 to 10 cm size, placed in a layer 7 to 15 cm thick on a clay rich road surface. In locally deep rutted areas with heavy clay soils, layers of 15 to 45 cm of chips have been used successfully to pass loaded logging trucks. Some advantages have been gained by mixing chunkwood with soil or aggregate. Limited use has been observed to date on steep grades.

Thus chip and chunkwood surfacing has generally performed well in pilot projects to date, and is considered a viable alternative for logging road surfacing. However the material may have a relatively short service life, depending on the environment where it is used. Submerged in swamps, materials have lasted 15 years. The production of chips has also been relatively expensive, with limited equipment to produce the chips, thus minimizing the cost-effectiveness of this treatment. Where aggregate is available, it will likely continue to be the most desirable surfacing material. Where aggregate is not available or excessively expensive, use of wood products such as chips (assuming equipment is available to produce them) may be a cost-effective alternative for some roads.

Variable tire pressure, or Central Tire Inflation (CTI) can be used effectively to cross soft soils and reduce road damage, because of low contact pressures between the tire and the ground, better distributing the load, and less rider "bounce". Studies have shown that low tire pressures and CTI has been very effective to improve trafficability across soft soils, reduce road maintenance costs, and decrease wear to vehicles. Thus it has many desirable advantages. However it requires specific wheels and tires suited to low-pressure use and it is inefficient or unsuitable on paved roads. Thus if a vehicle travels both on soft soil and paved roads, a system of tire inflation must be available.

Drainage Crossing Structures (Log Culverts, Log Bridges or old CMP)
Good use is being made of the available log (wood) resources for log bridges, stacked log, and hollow log culverts. They are generally appropriately placed, though additional culverts are needed in some areas, and others would be cheaper and better to build with low fords or rolling dips. The major advantage of log culverts is their low cost, using local log materials. The major disadvantage of log culverts is their limited flow capacity. Hollow log culverts are typically relatively small, seldom over 30 to 50 cm in diameter, and stacked log culverts also have a relatively small flow capacity. This small flow capacity also leads to more frequent plugging with debris and sediment. Their use is particularly appropriate on local access roads with a short period of use and then the logs should be pulled out until the road is again used (in 20 to 25 years).

On the higher standard, collector roads conventional metal or concrete culverts and more desirable because of their increased capacity, or small log bridges can be built with a span and capacity needed for the site. Simple bridges are seen made either of logs, steel girders, or concrete slabs. Log bridges are no doubt the least expensive to construct, and the concrete structures have the longest design life (typically 75 to 100 years). Note that the log structures will likely have a short useful life, but with proper selection of wood species and good construction practices and design details, the structures can last many years. Poorly build log bridges in contact with the soil or with soil covering, may last 10 years. A well constructed bridge with quality hardwood can last over 25 (possibly to 50) years.

Interesting use of log bridges and abutments is seen throughout the region. Most are typically simple log sill or “log crib” abutments, with single depth log girders placed across them. One recently constructed bridge has a “cantilever” log abutment with long logs buried into the roadway fill, parallel to the road, and then transverse log sills to support the log stringers. This design has the advantage of being less susceptible to stream channel scour since the bridge is supported by the logs buried back into the roadway approach fill rather than vertically down to the stream channel. However some basic channel scour protection, such as use or rock riprap, logs buried into the streambanks, etc would be desirable to prevent undermining of the cantilever logs.

On NR6 most old culverts are Corrugated Metal Pipe (CMP) and many now appear to need either replacement or maintenance. Most appear well located, though some sections of road need additional pipes (or dips). Many pipes have the cover soil removed, such that traffic is driving directly on the metal pipe. Many of these pipes are likely partially crushed or damaged at the inlets or outlets. Many others appear partially or totally plugged with vegetation or sediment. To make this road drainage system function properly the pipes need to be cleaned or replaced, and some additional pipes installed.

The **“Design”** of drainage structures, for a certain capacity to pass the design flow expected during the design life of the structure, as is done in conventional drainage structure design practice, is somewhat impractical and difficult in this region (as well as regions like the Amazon). First, topographic maps and information, or air photos, are limited, non-existent, or of a very large scale (1:250,000+) with little usefulness to drainage calculations. Some areas have maps with a 1:50,000 scale exist, but with poor quality definition of the drainages. Thus definition of the **drainage area** is difficult.

Next, runoff characteristics of the terrain are unknown, or variable with the jungle acting like a "sponge" up to a certain point of precipitation. Also little or no gauging station or other flow data exists on the rivers in the region. Last, limited rainfall data exists for the region, other than general isohyets of total annual rainfall across the country. No rainfall-intensity-duration data has been found, which would help in the design of local drainage structures (for small watersheds, say to a few hundred hectares in size).

Thus little data or few tools exist for doing actual drainage calculations or estimating risk to structures for various rainfall events or recurrence intervals for storms. What **does** exist are on-the-ground observations or local accounts of typical or high water flows, and occasionally other evidence of high flow events. Thus old bridges in the region appear to be constructed with high clearance and adequate freeboard for major storm events. Local and small drainage crossing structures need to be based on a "temporary structure concept" or local experience and judgment. This approach could be improved with some effort and study into local drainage characteristics and possibly a survey of agencies or universities for some data applicable to this work.

Streamside Management Zones (SMZs)

Streamside management zones, or areas of limited activity and disturbance along the streams, are a useful concept to minimize damage to the creek-side riparian areas and to minimize sedimentation that can directly enter the streams from nearby activities. Width of the SMZ is typically a function of the soil type and erosiveness, slope of the ground, and density of vegetation. SMZs are commonly 10 to 50 meters wide on each side of the drainage. Activities or logging is not prohibited in this area, but is limited to minimize disturbance or the streamside corridor.

The SMZ concept is based upon environmental protection of the ecologically valuable stream corridor and its streambanks. This zone is also the final buffer area where sediments can be trapped before directly entering the water. This streamside riparian zone also commonly serves as a major wildlife migration or movement corridor. Thus SMZs serve a valuable ecological and sediment control function.

Additionally, protection of this zone and minimizing debris or sediment in the stream channel serves an important engineering function. Many drainage structures fail due to clogging, plugging, or loss of capacity due to sediment accumulation. Keeping the channel clear of debris is one of the common bridge/culvert maintenance tasks and so SMZ protection minimizes the need for this maintenance or risk of structure failure.

Road Closures and Limiting Access to Logged Areas

The logging companies, and particularly SBL, have the advantage of being able to control use of their logging roads, both during the logging operations and after the operation. Their stated plan is to close most local area roads after log extraction use and keep them closed until the next rotation cycle, planned for 25 years.

There are many advantages to closing the roads or controlling access to the land after logging. These include preventing illegal logging by other companies or locals;

preventing damage to the roads by use during wet periods; preventing ingress or colonization into the area by local or displaced populations; and minimizing poach and bushmeat hunting in the area, thus protecting local wildlife.

Since wildlife degradation is a key issue in this region, as well as most of the Congo, and an issue of major concern worldwide, logging companies such as SBL have a unique opportunity to help wildlife conservation through their land management and road control. A key issue then is to ensure that the companies maintain the road closures and controls as stated in their area management plans.

The issue of using forest roads (and other roads) for bushmeat hunting is problematic but needs to be addressed as much as possible. Even when main roads are gated or have guards, some traffic still seems to enter the areas, for a variety of reasons. Also for closed roads, people reportedly still walk long distances into the forest to hunt, using the road opening for access and for camping. Thus solutions (or mitigations for wildlife) appear to need a variety of measures, including road closure or control; forest guards; enforcement with fines or punishment; alternative inexpensive sources of meat; control on hunting tools, particularly rifles; limited hunting around camps; and local environmental education.

Obviously the best wildlife protection is afforded by the establishment and maintenance of parks and reserves with adequate protection and limited or no road access. Forest concessions can offer valuable buffers around these parks, or just maintain other forest habitat. No new road construction or ingress into areas would be best for most wildlife, but since the concessions will be logged, road control is clearly a desirable mitigation once the roads have been constructed.

Other schemes to limit road access for wildlife conservation and to limit bushmeat hunting include area-wide transportation planning to identify key routes, areas where traffic can be controlled, key inspection points, or strategies to improve some routes and keep other roads low standard with limited access in critical wildlife areas. Obviously such schemes require government, inter-agency, and community cooperation and involvement, as well as some funding to maintain road control and inspections. Such efforts should be in conjunction with local conservation and education programs to heighten awareness of the problem. Some schemes may be beyond the control of local logging companies, while in others they may be a cooperator in some efforts.

Wildlife protection or road closure and enforcement could be incorporated as a requirement of “certification” by groups such as the Forest Stewardship Council (FSC), Smartwood, etc. as part of their overall goal of sustainable forest management and resource protection.

<u>Photos</u>

Photo 1-Well maintained Principal Haul Road.

Photo 2- Excessive road and clearing width on a Local Road.

Photo 3- Excessive ground disturbance during new construction.

Photo 4- Deep leadoff ditches requires after excessive earthwork.

Photo 5- Ditch erosion caused by lack of surface drainage.

Photo 6. More surface erosion caused by concentrated flows and lack of surface cross-drainage.

Photo 7- Mud hole in National Road 3 due to lack of Maintenance.

Photo 8- Nearly impassible mud holes when raining (NR 3).

Photo 9- Unstable, slumping vertical cutbank.

Photo10. Well vegetated stable vertical cut in a clay rich soil.


Photo 11- Typical log stringer bridge utilizing locally available logs.


Photo 12- Commonly used log culverts-limited flow capacity, but inexpensive and appropriate for temporary roads.

Photo 13-Local quarry, near the SBL mill, with excellent pit run material.

Photo 14- Spot rocking (background) with local laterite rock on a steep grade.

Photo 15- SMZ with considerable disturbance at a bridgesite.

Photo 16- Road reconstruction (with major disturbance) due to poor road location.

Photo 17- Muddy water and sedimentation caused by poor road construction practices.