CLEAN DEVELOPMENT MECHANISM
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Annex 6: Sampling protocol for measuring GHG emissions in Bumbuna Hydroelectric Project (BHP)

February 2007

1 PROJECT DESCRIPTION

The BHP will be a run-of-river hydropower plant built on the Seli river, 2.4 km upstream of the Bumbuna falls. The dam consists of an 88 m high rock filled with an asphalted concrete upstream face, and a crest-length of 440 meters. The above-ground powerhouse set at the base of the dam will house 2 x 25 MW turbo-generator units.

The reservoir will be Y-shaped, 30 km long, with width between 0.2 and 1 km, a surface area at the maximum operating level (240.5 m_{asl}) of 21 km^2, and a water volume of 445 x 10^6 m^3. The hydro power plant will have a maximum operating capacity of 50 MW. The water level of the reservoir will be controlled by two “morning glory” spillways. Apart from power generation, the BHP will be capable of 35 x 10^6 m^3 regulation for downstream flood control. The spillways discharging through left and right bank tunnels have a total design discharge of 3,000 m^3/s.

The hydrology of the Seli River reflects the seasonal rainfall pattern characterized by very wet winters followed by 4-5 months of markedly dry periods.

Despite a relatively short residence time (≈1.1 month or 33 d calculated from the Table 8.8.1-1, p. 164 of the Bumbuna hydroelectric project environmental impacts study, 2004), it is possible that the water mass will be stratified. This will create a large lower layer, devoid of oxygen due to lack of mixing. Forced mixing using compressed air is considered as a mitigation measure to increase fish productivity. Nonetheless, stratification of the water column is considered and will be taken into account because of the increase in CH_4 production.

The amount of available organic matter will decrease during impoundment of the reservoir if the vegetation is cleared from the reservoir area before impoundment. This will remove 1570 ha of forest, including 380 ha of riparian and 450 ha of mixed-tree savannah, including commercially valuable trees with trunk volume of > 500,000 m^3.

2 SAMPLING PROTOCOL

The following sampling protocol is aimed at assessing gross GHG emissions from the Bumbuna reservoir. In regard to the three distinct pathways of GHG emissions, we propose a particular sampling design, level of effort (number of stations and field campaigns), and sampling method for assessing diffusive fluxes, bubbling and degassing in the Bumbuna reservoir. The suitability of the proposed level of effort in regards to the desired level of precision (assumed here to be ± 10 % of total yearly GHG emission) will have to be tested when data from Bumbuna reservoir will become available, by following the bootstrap approach described in the *Protocol for measurements of GHG emissions from tropical reservoirs*.

Many of the factors listed in Table 2 of the protocol mentioned above are correlated in Bumbuna reservoir, because of its valley-type shape. Indeed, two main gradients of potential variability sources can be distinguished in this reservoir: 1) a transversal gradient going from the shore to the centre of the reservoir and spanning variations in water depth and vegetation-soil type (once flooded, riparian forests will occupy the deepest part of the reservoir, next to the submerged bed of the Seli river, with a gradual transversal change to mixed tree savannah and cultivated land toward shallower depth of the reservoir) and 2) a longitudinal gradient characterized by the transition from riverine to lacustrine conditions (with variations in depth, thermal stratification of the water masse and water bottom temperature).

For these reasons, we propose to adopt a systematic sampling plan for assessing diffusive GHG fluxes in Bumbuna reservoir. A systematic sampling plan would be appropriate to integrate the two main gradients of potential variability sources (which could result or not in a gradient in GHG diffusive fluxes) and provide a representative estimate of the mean of Bumbuna reservoir GHG emissions through diffusion.

A systematic sampling plan is simple to apply, allowing to sample evenly across the whole reservoir. Furthermore, the systematic distribution of the sampling stations along the transversal and longitudinal axes will provide adequate coverage of the reservoir and will take into account possible gradients in GHG diffusive fluxes.

2.1 Spatial distribution of the sampling plan

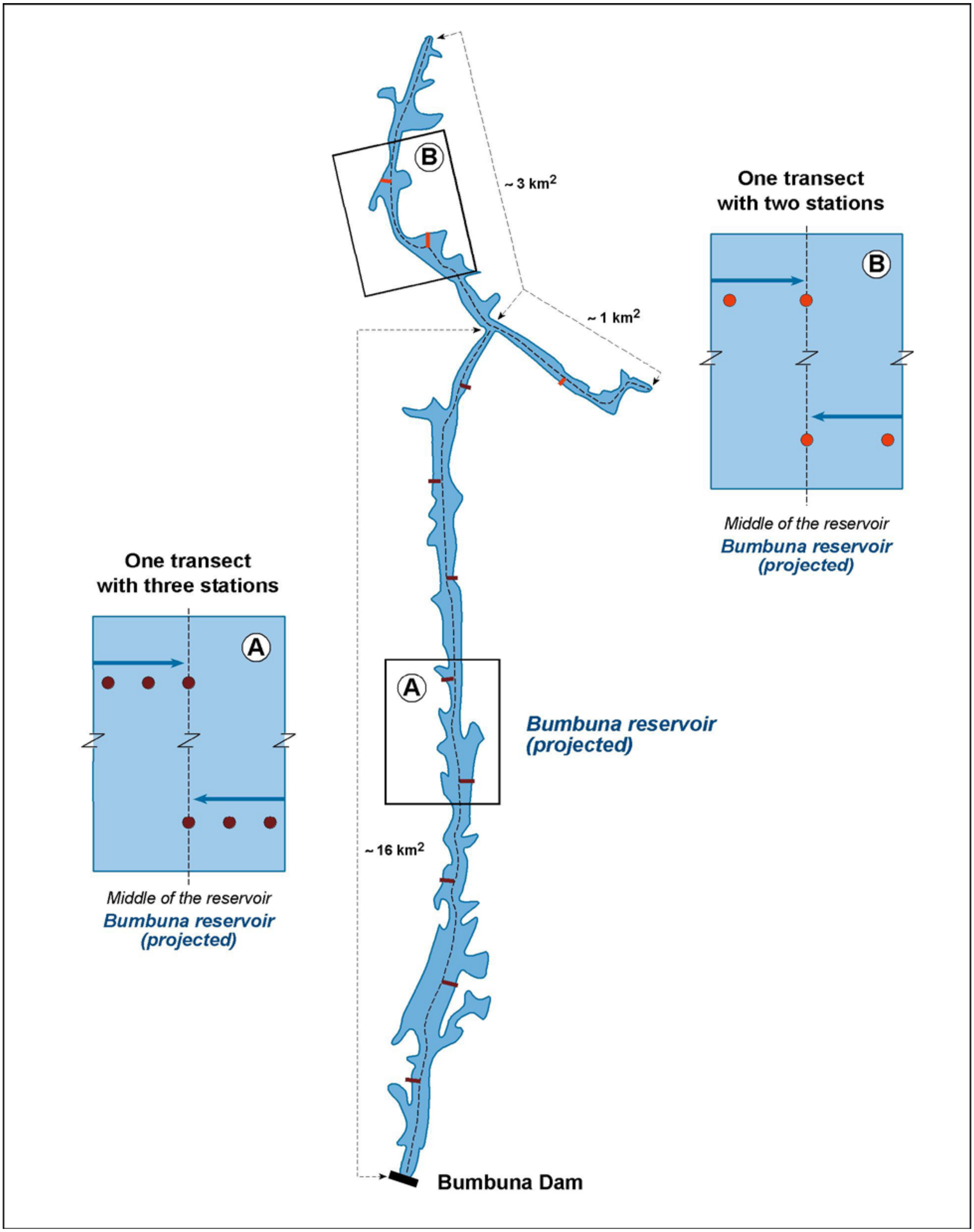
Diffusion

The systematic sampling plan proposed for estimating GHG emissions through diffusion consists of 11 transects perpendicular to the reservoir central axis, distributed evenly across the length of the reservoir, and alternating between the right and left shoreline

(Figure 1). Eight transects are located in the main branch, downstream of the confluence of the Mawoloko and Seli rivers, and 3 transects are located upstream of the confluence. The distribution of the stations between the main branch of the reservoir and its two ramifications (above Mawoloko and Seli river confluence) is made according to their relative surface area.

Each transect includes two to three stations spaced evenly along the transect. The shoreward station will be at the 10 m isobath (the 0 to 10 m depth range is sampled with the bubbling approach) and the last station will be at the center of the reservoir. At each station, triplicate measurements are performed to obtain a mean flux. To eliminate any bias in the location of the sampling transects, the coordinates of the first transect will be picked up randomly within the first reach of the reservoir. Each reach will be of equal length so that the 11 transects will be equally spaced and will alternate with each other on either side of the reservoir. The location of the sampling transects could stay the same for all sampling campaigns, which will enable the pairing of the stations in order to assess the existence of any seasonal trend in GHG emission.

FIGURE 1 — Illustration of the spatial sampling design protocol proposed for the estimation of the Bumbuna reservoir GHG emissions through diffusion in the case 30 stations are sampled at each campaign



Bubbling

Because bubbling is limited to the 0-10 m depth range, all 30 stations will be distributed along transect lines running perpendicular to the shore. Three stations per transect will be place at the 1 m, 3 m and 7 m isobaths and the transect lines should be placed in continuity with the transects used for sampling of the diffusive fluxes (> 10 m). Each station includes two collecting funnels in order to obtain duplicate measurements.

GHG exportation downstream of dam

The projected Bumbuna reservoir is a run-of-river reservoir, characterized by a high water renewal time (around twelve times a year for a water residence time of around 1.1 month). As such, it will be characterized by a relatively high water turbinated discharge compared to its surface area (higher than 6 $m^3s^{-1}km^{-2}$, comparable to Itaipu and Serra da Mesa), which would probably make the degassing downstream of the dam an important component of the total GHG emissions compared to diffusion.

Because the Bumbuna reservoir is projected to be flooded in 2007, the GHG concentration in the natural river may not be measured. The baseline concentrations should then be replaced by a reference concentration (in duplicate measurements) of CO_2 and CH_4 measured at each and every field campaign (n = 4) from surrounding lakes or at the upstream reach of the reservoir where the main inputs are coming in. The latter location is possibly better as the limnological characteristics of the surrounding lakes may differ from those of the reservoir.

To calculate the yearly degassing and exportation downstream of the dam daily discharge at the dam and GHG concentrations of the turbinated water for each campaign (if one cannot directly measure the gas concentration near the turbine, water samples from the water intake or just upstream of the dam at the depth corresponding to the water intake will be appropriate) are required.

2.2 Temporal distribution of the sampling plan

The hydrologic regime of the Seli River is pluvial with two main seasons. The variation of the Seli River discharge in relation to the water residence time of the reservoir (calculated from the Table 8.8.1-1, p. 164 of the Bumbuna hydroelectric project environmental impacts study, 2004) are shown in Figure 2. The different water residence times are well represented if sampling occurs in December, March, June and September, or in February, May, August and November (Figure 3). The date of the first campaign will be determined randomly between the months of December or February, with the following campaigns occurring 90 (365 days/4), 180 and 270 days later. The proposed approach prevents a situation where randomly-picked periods within each main seasons may be close together, resulting in long unsampled periods. Each year, the sampling campaigns will occur at the same dates. This approach will enable us to pair the

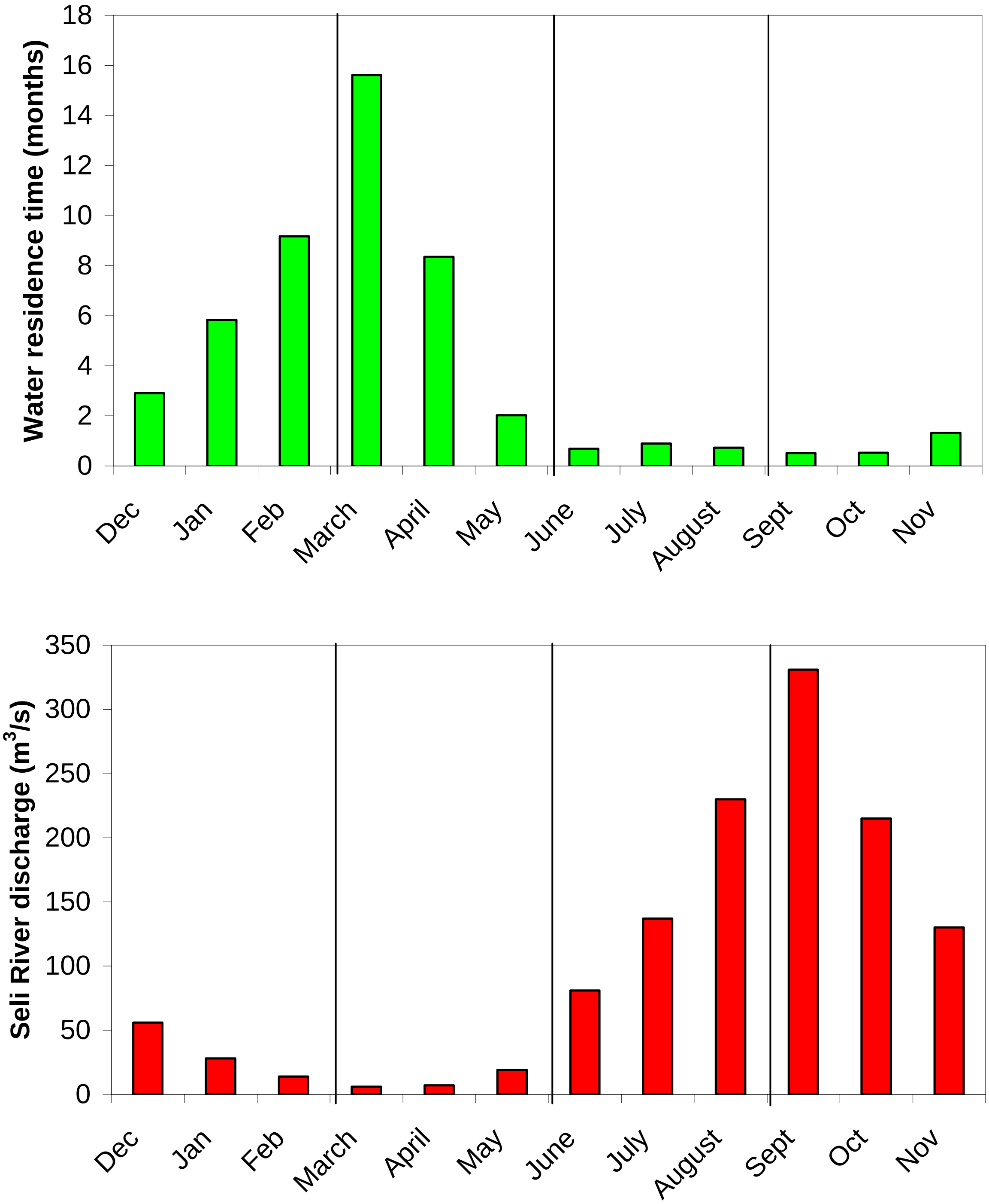
observations after two or several years of sampling and produce a two-way (space, time) factorial design that will allow a test of the interaction between space and time to be computed and enabling cross-testing of seasonal and yearly relationships.

We suggest considering only the diurnal cycle as a sampling constraint with no samples taken during the mid-day period (11:00 a.m. to 14:00 p.m.) when fluxes may be lower due to high levels of phytoplanktonic photosynthesis (CO_2 absorption). Night time diffusive fluxes may be higher due to respiration, but mixing by wind is usually higher during the day. Thus, daily sampling should provide conservatively high fluxes and will also offer safer working conditions.

The GHG emissions from bubbling will be measured following the same seasonal frequency used for the determination of the diffusive emissions (n = 4). During each campaign, sampling will occur for a period of 24 h at each station. This will require a certain number of funnels that will be rotated around the reservoir during a given campaign. Time of installation and retrieval must be noted in order to be able to track daily variation/anomalies and to express the fluxes as a function of time.

The GHG emissions attributed to the gas export from the reservoir will be measured following the same seasonal frequency used for the determination of the diffusive and bubbling emissions (n = 4). During each campaign, sampling will occur once.

FIGURE 2 —Calculated water residence time (months) in Bumbuna reservoir in relation to the Seli River monthly discharge. Data for the calculation of the water residence time are on p. 164 of the Bumbuna hydroelectric project EIA (2004), volume 2



3 CONCLUSION AND GENERAL NOTES

Since bubbling is limited mostly to shallow depths (less than 10 m), which represent only around 15 % (2.4 km^2) of the Bumbuna average surface area (15 km^2), we assume that the relative importance of bubbling will be small compared to degassing. We believe degassing could be the major pathway of GHG emissions for the Bumbuna reservoir. Degassing can be more precisely assessed than diffusion and bubbling since the daily water turbinated discharge is known and the gas concentrations of the turbinated water can be measured quite easily once a week. Thus, the Bumbuna reservoir gross GHG emissions should have a relatively low relative error (95 % confidence limits) compared to larger reservoirs.