Draft approved baseline and monitoring methodology AM00XX

"Increased electricity generation from existing hydropower stations through Decision Support System optimization"

I. SOURCE AND APPLICABILITY

Source

This baseline methodology is based on the NM0186 methodology "Increased electricity generation from existing hydropower stations through Decision Support System optimization" submitted by Quality Tonnes and the World Bank Carbon Unit.

For more information regarding the proposals and their consideration by the Executive Board please refer to http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html.

This methodology also refers to the approved consolidated methodology ACM0002 "Consolidated baseline methodology for grid-connected electricity generation from renewable sources¨ and to the latest version of the "Tool for the demonstration and assessment of additionality".[1]

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable"

Applicability

This methodology is applicable to existing grid-connected hydropower systems that may include multiple hydro generation units linked in a cascade, including both run of the river and reservoir-based units, where the project activity increases annual electricity generation through the introduction of a Decision Support System (DSS)[2] that optimizes the operation of the existing hydropower facility/facilities.

The methodology is applicable under the following conditions:

- Where the operation of hydropower systems is not currently optimized using a DSS, with optimization controls or modeling;
- Where, at a minimum, one complete year of recorded data is available to establish the baseline relationship between water flow and power generation;
- Where power generation units, covered under the CDM project activity, have not undergone and will not undergo significant upgrades beyond basic maintenance (e.g., replacement of runners) that affect the generation capacity and/or expected operational efficiency levels during the crediting period;
- Where no major changes to reservoir size (e.g. increase of dam height) or to other key physical system elements (e.g. canals, spillways) that would affect water flows within the project boundary, have been implemented during the baseline data period or will be implemented during the crediting period;

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[1] Please refer to: <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>

[2] A DSS is an integrated set of computer programs (modules) that use forecasting methods and both optimization and simulation techniques to optimize the long-term and short-term benefits of power system operation.

- Where the project activity only includes the optimization of generation units that generated and supplied power to the electricity system during the year(s) for which historical data for the baseline was collected;
- Where either no additional hydro power units are located downstream of the last hydropower unit within the project boundary or the first hydropower unit downstream the project boundary has the capacity to regulate at least 24 hours of maximum flow from upstream.[3]

II. BASELINE METHODOLOGY

Project boundary

The project site includes all of the hydropower generating units for which the DSS tool will be installed. The **spatial** extent of the project boundary includes the project site and all power plants connected physically to the electricity system to which the hydropower generating units in the project site is connected.

For the baseline determination, project participants shall only account for CO_2 emissions from electricity generation in fossil fuel fired power plants that are displaced due to the CDM project activity. The grid emission factor will be calculated according to approved consolidated methodology ACM0002 "Consolidated baseline methodology for grid-connected electricity generation from renewable sources". The grid boundary for the project is as described in the latest version of approved consolidated methodology ACM0002.

Emissions sources included in or excluded from the project boundary

	Source	Gas	Included?	Justification / Explanation
Baseline	Electricity generated from the grid	CO_2	Yes	CO_2 is emitted when fossil fuels are burned to generate electricity. The project activity would displace those fossil fuels with enhanced hydropower output.
		CH_4	No	-
		N_2O	No	-
Project Activity	Emissions from the CDM project	CO_2	No	In terms of project emissions, the project is enhancing the use of existing hydropower capacity to generate additional hydropower. No fossil fuel emissions will be used to generate this additional electricity and thus there will be no project emissions.
		CH_4	No	-
		N_2O	No	-

[3] Twenty four hour (24 hrs) capacity in cubic meters (m^3) = Maximum observed annual flow (m^3/s) *24 hr*3600 s/hr * 0.5. Note that factor 0.5 reflects that the storage must be 50% of the flow volume to re-regulate the inflow to the average daily value.

Procedure for identification of the most plausible baseline scenario

The methodology determines the baseline scenario through the following steps:

> Step I: Identify all alternatives to the proposed CDM project activity that deliver a similar level of additional generation to the grid;
>
> Step II: Identify the most likely scenario (the baseline scenario) from the alternatives identified in Step I using the investment and barriers analysis steps (Step 2 and Step 3, respectively), as defined in the most recent version of the *"Tool for the demonstration and assessment of additionality"*, together with additional guidance provided for these steps in the Additionality section below.

Step I: Identify alternatives to the project activity

Project participants shall identify realistic and credible alternatives(s) to the project activity including the following possible alternatives:

Alternative #1: Status Quo. Continuation of the current water management practices.

Alternative #2: Changes to hydro system operation or facilities (other than the project), including dam height, turbine replacement, spillway dimensions, and other changes that would materially affect the flow-output relationship.

Alternative #3: The proposed project activity, not undertaken as a CDM project activity.

The alternatives proposed in this Section are only indicative. Project proponents should propose other possible alternatives that are reasonably foreseeable.

Step II: Identify the most likely scenario (the baseline scenario) from the identified alternatives

Project participants, after identifying the alternatives to the project activity shall apply the barrier analysis and investment analysis as outlined in Steps 2 and 3 of the most recent version of the *"Tool for the demonstration and assessment of additionality*" as further elaborated in the Additionality section below.

The baseline scenario should be the alternative that faces the fewest barriers among the identified alternatives in Step I. If more than one alternative remains subsequent to barrier analysis, then the baseline scenario will be identified using investment analysis. The baseline scenario is then the alternative that is economically most viable as estimated using Step II of additionality assessment tool. Supporting documentation and evidence demonstrating the barriers and financial constraints of each of the non-baseline alternatives faces shall be presented to the DOE.

National/Sectoral Policies: In cases where actively enforced laws mandating the use of Decision Support Tools are in place, the project activity not undertaken as a CDM project (Alternative 3) will be considered the baseline scenario.

This methodology is only applicable if Alternative 1, i.e., continuation of current water management practices, is the most likely baseline scenario.

Additionality

The project should be demonstrated as additional using the most recent version of the *"Tool for the demonstration and assessment of additionality"*, together with additional guidance provided below:

Sub-step 3a. Identify barriers that would prevent the implementation of type of the proposed project activity:

Establish that there are barriers that would prevent the implementation of proposed project activity from being carried out if the project activity was not registered as a CDM activity. Such barriers may include, among others:

Investment barriers:

- Financing capacity of the project proponent vis-à-vis other investment opportunities;
- Debt funding may not be available for innovative project activity;
- Lack of access to international capital markets due to real or perceived risks associated with domestic or foreign direct investment in the country where the CDM project activity is to be implemented;
- Subsidies may exist that inhibit investments in energy efficiency;
- The electric utility may not recover through revenues the cost of generation, and this could inhibit major investments;
- Potential lack of access to credit due to poor revenues; or,
- Inability of the management to dedicate resources, etc for implementation of the CDM project activity.

Technological/lack of familiarity barriers:

- Lack of familiarity or first-of-its-kind project significantly hinders the ability to implement the proposed project activity;
- Skilled and/or properly trained labor to operate and maintain the technology is not available;
- Education/training institution for training operators are not present in the host country leading to equipment disrepair and malfunctioning; or,
- Lack of infrastructure such as appropriate meters and communications links for implementation of the technology.

Step 4. Common practice analysis:

The project developer may interview electricity utilities, in the selected country or region, and the manufacturers of the DSS software/optimization technology to assess how common is the CDM project activity.

The CDM project activity is not a common practice if:

- the project type has not been implemented in the country (or region for large countries); and
- companies that provide the technology, used in the CDM project activity, have minimal business in the country where the CDM project is being implemented; and
- utility managers are unfamiliar with this type of project.

If the optimization has taken place somewhat frequently elsewhere in the country or region, the project developer would need to show the extenuating circumstances that made such project happen and how it would not be replicable.

With respect to Steps 2, 3 and 4:

For the investment, barrier and common practice analyses, project participants should provide the following evidence to the DOE:

- Letters from the electricity utility implementing the proposed CDM project activity indicating their unfamiliarity with the hydro-optimization technology;
- Letters from one or more technology providers/developers that indicate average penetration rates in developed markets and whether similar projects have been developed in the country or region;
- Financial statements indicating the revenue losses and overall financial health of the electricity utility implementing the CDM project activity;
- Least-cost capacity expansion planning or feasibility studies, if available, that show that electricity utility implementing the proposed CDM project activity has not considered the CDM project activity as an option in these studies. This could include a list of priority investments for the utility. If the list does not include hydro-optimization but includes other projects, it shows that the CDM enables bringing the proposed project forward;
- Existing tariff rates or other information that show the income received from additional hydropower generation from implementing the CDM project activity would not translate into additional income, thus making the investment not cost-effective (for the investment analysis).

Baseline Emissions

The following six steps are used to estimate baseline emissions. If generating units within the project site, where DSS is implemented, do not share a connected water source, the estimation of the baseline emissions will be sum of the baseline emissions estimated using Steps 1 through 6 for each water course separately. A Data Book shall be prepared prior to the implementation of the Decision Support System containing all functional relationships (charts) for each generating unit, including the flow-generation functions.

Step 1: Collect data for estimating the baseline flow-output relationship

The flow-output relationship is developed from baseline data collected for each generating unit and spillway within the project boundary, as described in the steps below. All data available within the most recent three calendar years must be collected and applied to the methodology below. In cases where less than three full years is used, the DOE must verify the unavailability of data. A minimum of one calendar year's data must be used, as required by the applicability conditions.

Step 2: Estimate weekly baseline flow for each week (generating units and spill)

The weekly flow (Q_x) is sum of the flow through generating unit(s) and the spillway(s), estimated on an hourly basis, as follows:

$$Q_x = \sum_{hpu=1}^{N} \sum_{h=1}^{168} Q_{hpu,h} + \sum_{SW=1}^{M} \sum_{h=1}^{168} Q_{SW,h} \qquad (1)$$

Where:

Q_x	Flow during week 'x' for each generation site (m^3/week).
$Q_{hpu,h}$	Flow through generation unit 'hpu' during hour 'h' in week 'x' estimated using relationship provided in equation 2 (m^3/hour).
$Q_{SW,h}$	Flow over the spillway 'SW' for hour 'h' during week 'x', estimated using equation 3 (m^3/hour).
N	Total number of hydro power generation units 'hpu' within the project site on the same water course (number).
M	Total number of spillways within the project site on the same water course (number).

<u>Step 2a: Deduce Flow through Generating Units.</u> The hourly flow through each generating unit is determined using the records of measured power output for that hour and the characteristic specifications of the generating unit. A curve for each HPU known as a "Hill Diagram" [4] will be constructed that accurately pinpoints its *power* versus *flow* and *head*. The form of the flow-generation curve for each generating unit is represented by a third order, polynomial equation that relates measured power output to measured head and flow, as follows.

$$EG_{hpu,h} = a + b \cdot Q_{hpu,h} + c \cdot Q_{hpu,h}^2 + d \cdot Q_{hpu,h}^3 \tag{2}$$

$$\mathrm{a} = \mathrm{a}_1 + \mathrm{a}_2 \cdot \mathrm{H}_{\mathrm{hpu}} + \mathrm{a}_3 \cdot \mathrm{H}_{\mathrm{hpu}}{}^2 \tag{2.1}$$

$$\mathrm{b} = \mathrm{b}_1 + \mathrm{b}_2 \cdot \mathrm{H}_{\mathrm{hpu}} + \mathrm{b}_3 \cdot \mathrm{H}_{\mathrm{hpu}}{}^2 \tag{2.2}$$

$$\mathrm{c} = \mathrm{c}_1 + \mathrm{c}_2 \cdot \mathrm{H}_{\mathrm{hpu}} + \mathrm{c}_3 \cdot \mathrm{H}_{\mathrm{hpu}}{}^2 \tag{2.3}$$

$$\mathrm{d} = \mathrm{d}_1 + \mathrm{d}_2 \cdot \mathrm{H}_{\mathrm{hpu}} + \mathrm{d}_3 \cdot \mathrm{H}_{\mathrm{hpu}}{}^2 \tag{2.4}$$

Where:

$EG_{hpu,h}$	Observed power output of 'hpu' unit for hour 'h' during week 'x' (MWh).
a, b, c, d	Coefficients that are a function of head, calculated as per equations above .
$Q_{hpu,h}$	Flow through generation unit 'hpu' during hour 'h' (m^3/hour).
a_i, b_i, c_i and d_i	The power polynomial coefficients for each generating unit based on "*hill diagram"* information provided by the owner or manufacturer .
H_{hpu}	Head acting on the generating unit hpu (headwater level less tail water level) for each hour 'h' (m).

<u>Step 2b: Calculate Spillway Flows.</u> Spillway flows are calculated with the application of a "rating equation" which relates the flow through the spillway gate opening to monitored parameters - the water level and the gate opening[5]. Rating equation provided by the owner and/or equipment manufacturer shall be used for estimating the spillway flows. For example, a typical equation for spillway overflow <u>with a radial gate partially open</u> is:

$$Q_{SW,h} = C_0 \cdot L_e \cdot O \cdot \left(WL_h - E_{sill}\right)^E \cdot 3600 \tag{3}$$

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[4] Design of Small Dams, US Bureau of the Interior, Bureau of Reclamation, Chapter IX, Spillways

[5] Design of Small Dams, US Bureau of the Interior, Bureau of Reclamation, Chapter IX, Spillways Water Resources Engineering, Linsley and Franzini, McGraw Hill

Where:

$Q_{SW,h}$	Hourly spillway flow (m^3/hour).
C_o	Known coefficient taken from manufacturer/owner data.
L_e	Length of the gate measured as built (m).
O	Vertical opening (m).
WL_h	Water level during hour 'h' (m).
E_{sill}	Elevation of the sill measured as built (m)
E	Known coefficient taken from manufacturer/owner data.

Spillway flows will be calculated for each hour and aggregated weekly over the year. These values are used in Step 3.

Step 3: Establish the flow-output (generation) relationship

Tabulate weekly total flow (generation flow and spillway flow) estimated in the previous step along with recorded power generation during the corresponding week of the baseline period. Estimate the relationship between *total weekly flow* and *total weekly generation* for the baseline through regression analysis using polynomial equation form, taking into account guidance provided by the Board[6]. The estimated equation should be of the form

$$EG_x = f(Q_x) = a + b_1 \cdot Q_x + b_2 \cdot Q_x^2 + ... + b_n \cdot Q_x^n \tag{4}$$

$$EG_x = \sum_{hpu=1}^{N} \sum_{h=1}^{168} \left(EG_{hpu,h} \right) \tag{5}$$

Where:

EG_x	Recorded value of power generation for week 'x' estimated as sum of recorded observation of power generation in each of the units 'hpu' for hour 'h' in the week 'x' (MWh).
Q_x	Estimated value of flow in the week 'x', estimated as per Step 2 (m^3/week).
$a, b_1 ... b_n$	coefficients of the estimated regression equation.

The criteria for determining the degree of polynomial 'n' is as follows

(i) The value 'n' for which the adjusted R^2 of the equation is highest.
(ii) Estimates of parameters a, $b_1,…,b_n$ are significant at the 5% confidence level.

Step 4: Determine Baseline power generation

Use the flow-output relationship defined in Equation 4 to estimate baseline electricity output during each week of the project period ($EG_{Bl,x}$), and sum this for each week of the year 'y'.

$$EG_{BL,y} = \sum_{x=1}^{52} EG_x^{Bl} \tag{6}$$

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[6] Please see Annex 7 of EB21 meeting report.

$$EG_x^{Bl} = f(Q_x^{\Pr}) + 1.96 \cdot SE(EG_x^{Bl}) \qquad (7)$$

Where:

EG_x^{Bl}	Estimated electricity that would have been generated corresponding to flow $Q_x^{\Pr}$ estimated in the week 'x' of project crediting period 'y' (MWh).
$Q_x^{\Pr}$	Flow for week 'x' measured during the project year "y" (m^3/week).
$SE(EG_x^{Bl})$	Standard error of the estimate EG_x^{Bl}. The procedure for estimating *SE* is given in Annex I (MWh).

Note that due to the inclusion of the second term in Equation 7, there is only a 5% chance that the estimated baseline output would be understated by the equation. Therefore, there would only be a 5% chance that weekly energy generation gains would be overestimated.

To be conservative, the project developer will not seek to claim credit for any weekly project results in which the flow (Q^{Pr}_x) falls outside the recorded boundaries of the baseline data[7].

Exclusion of any outlier data points should be documented with a clear rationale (atypical circumstances such as blackouts, major equipment malfunction and repair) and validated and/or verified by the DOE. In the project year, the project developer will not be able to claim any emission reductions in weeks where major atypical circumstances occur.

Step 5: Calculation of Project Electricity Generation

The total electricity generation for the project EG_y in year y is calculated as follows:

$$EG_{\Pr,y} = \sum_{x=1}^{52} \sum_{hpu=1}^{N} EG_{\Pr,hpu,x} \qquad (8)$$

Where:

$EG_{Pr,y}$	Electricity generated during the project in year 'y' (MWh).
$EG_{Pr,hpu,x}$	Total electricity generated by unit 'hpu' in week 'x' of year 'y' (MWh).

Step 6: Baseline emissions

$$BE = \left(EG_{\Pr,y} - EG_{Bl,y}\right) \cdot EF_y \qquad (9)$$

Where:

EF_y	CO_2 emissions factor estimated using ACM0002 (tCO_2/MWh).

CO_2 emissions factor for the entire electricity grid determined using the combined margin approach approved in ACM0002.

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[7] This gives the project developer incentives to use as many years of baseline data as possible. It also allows the baseline to conservatively and accurately normalize data in changing climates and in different withdrawal regimes.

Project Emissions

Project emissions are zero.

$$PE_y = 0 \quad (10)$$

Leakage

There is no leakage expected from the installation of a Decision Management System. The installation of software and meters will not lead to additional emissions.

Emission Reduction

$$ER_y = BE_y - PE_y \quad (11)$$

NOTE: It should be noted that if the actual generation is less than the baseline generation for a given week, it will be treated as a negative value and deducted from the total annual savings. If in the unlikely event a project activity temporarily results in a negative emission reduction, i.e. baseline emissions minus project emissions are negative, any further CERs will only be issued when the emissions increase has been compensated by subsequent emission reductions by the project activity. (See EB 21, item 18).

Changes required for methodology implementation in 2nd and 3rd crediting periods

Given that DSS systems could become standard practice over time in many regions (even in the absence of the CDM), the baseline scenario for the 2nd and 3rd crediting periods should be revisited. A regional common practice assessment should be conducted or consulted and if DSS systems are found to have become common practice in the region, the baseline scenario would then be considered to be the project itself.

Data and parameters not monitored

NOTE: Data for all the variables mentioned below shall be based on 3 years of historic records prior to start of the project activity. If for justifiable reasons, validated by the DOE, data is not available for 3 years, a minimum of one year data shall be used. DOE in its validation report shall report the reasons for non-availability of records for three years and its assessment of the situation. All the data used for establishing baseline relationships and baseline shall be reported in the registered CDM-PDD.

Data/Parameter	M
Data unit	Units
Description	Total number of spillways within the project site on the same water course, in the year before the implementation of the project activity.
Source of data	Project site.
Measurement procedures (if any)	Count the number of spillways within the project site on the same water course in the year before the implementation of the project activity. The data shall be stored until two years after the end of the crediting period.
Any comment	-

Data/Parameter	N
Data unit	Units
Description	Total number of hydro power generation units within the project site on the same water course, in the year previous to the implementation of the project activity.
Source of data	Project site.
Measurement procedures (if any)	Count the number of hydro power generation units within the project site on the same water course in the year previous to the implementation of the project activity. The data shall be stored until two years after the end of the crediting period.
Any comment	-

Data/Parameter	a_i, b_i, c_i and d_i
Data unit	Units
Description	The power polynomial coefficients for each generating unit based on “hill diagram” information provided by the owner or manufacturer. The “hill diagram” is the one which defines the three dimensional relationship between power output, head and flow
Source of data	Owner or manufacturer of the generating unit.
Measurement procedures (if any)	The data shall be stored until two years after the end of the crediting period.
Any comment	A “hill diagram” shall be included in the data book for every generating unit in the project boundary before validation. This essentially provides information derived in equations 2. Hill Diagrams for a generating unit are stationary and do not change measurably within the life of the project. Any changes, however unlikely, would be in the direction of deterioration of the unit and would make the results of the project more conservative (i.e. yield lower generation in project years).

Data/Parameter	H
Data unit	m
Description	Head acting on the generating unit (headwater level less tail water level)
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	Hourly data records for each hydropower generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	The equation given by the owner will provide accurate data. More importantly, the equation will give consistent results between baseline measurements and project year measurements.

Data/Parameter	C_o
Data unit	Units
Description	Known coefficient taken from manufacturer/owner data.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	Obtain the value before validation for each spillway in the project boundary. The data shall be stored until two years after the end of the crediting period.
Any comment	The equation given by the owner will provide accurate data. More importantly, the equation will give consistent results between baseline measurements and project year measurements.

Data/Parameter	L_e
Data unit	m
Description	Length of the gate measured as built.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	Obtain the value before validation for each spillway in the project boundary in order to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	The equation given by the owner will provide accurate data. More importantly, the equation will give consistent results between baseline measurements and project year measurements.

Data/Parameter	O
Data unit	m
Description	Vertical opening size of spillway.
Source of data	Measured during operations at the project site.
Measurement procedures (if any)	Hourly data records for each spillway in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	These measurements are very simple to make and accurate. More importantly the measurements will be completely consistent between the baseline year and the project year. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.

Data/Parameter	E
Data unit	Units
Description	Known coefficient taken from manufacturer/owner data.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	Obtain the coefficient before validation for each spillway in the project boundary in order to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	The equation given by the owner will provide accurate data. More importantly, the equation will give consistent results between baseline measurements and project year measurements.

Data/Parameter	E_{sill}
Data unit	m
Description	Elevation of the sill measured as built.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	Obtain the coefficient before validation for each spillway in the project boundary in order to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	The equation given by the owner will provide accurate data. More importantly, the equation will give consistent results between baseline measurements and project year measurements.

Data/Parameter	WL_h
Data unit	m
Description	Water level in week 'x'.
Source of data	Operations data log at project site.
Measurement procedures (if any)	Hourly data records for each spillway in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.

Data/Parameter	Headwater level
Data unit	m
Description	Headwater level.
Source of data	Operations data log at project site. Measured at head water entering generating unit.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project during the crediting period. The data shall be stored until two years after the end of the crediting period.
Any comment	Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.

Data/Parameter	Tail water level
Data unit	m
Description	Tail water level.
Source of data	Operations data log at project site. Measured at tail water leaving generation units.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.

Data/Parameter	$EG_{hpu,h}$
Data unit	MWh
Description	Observed power output of 'hpu' unit for week 'x'.
Source of data	Operations data log available at the project site.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Any comment	Meters shall be tested annually and calibrated as recommended by the manufacturer. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.

III. MONITORING METHODOLOGY

Monitoring procedures

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the comments in the tables below.

The following data for estimating the baseline relationship between power generation and flow shall be archived

1. All the water courses and corresponding hydro power generating units, included within the project site.
2. Relevant parameters of each hydro power generation unit, reservoir dam and the spill way characteristic to verify the applicability conditions.
3. Hourly power generation of each hydro power generation unit within the project site.
4. Parameters for Rating equation to estimate flow over the spill ways.
5. Estimated parameters of power generation and flow relationship, as estimated in Step 3 of Baseline Section in Baseline methodology.

The following data for estimating the baseline relationship between power generation and flow index shall be archived:

1. Estimated flow for each hour of the crediting period.
2. Projected estimate of baseline power generation corresponding to the project flow index.
3. Project power generation.

In addition, various elements of the hydro system (changes to turbines, dams, etc.) need to be monitored to ensure continued adherence to applicability conditions.

Data and parameters monitored

Data/Parameter	$EG_{Pr,hpu,x}$
Data unit	MWh
Description	Total electricity generated by unit 'hpu' in week 'x' of year 'y'.
Source of data	Measured at each hydro generation unit
Measurement procedures (if any)	The monitoring system installed with the DSS will gather and archive this data.
Monitoring frequency	Hourly, cumulated weekly.
QA/QC procedures	The data acquisition system used for the Decision Support Tool will provide highly accurate data. Meters will be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Data/Parameter	EF_y
Data unit	$kgCO_2/MWh$
Description	Grid electricity emission factor estimated using ACM0002.
Source of data	As per ACM0002.
Measurement procedures (if any)	As per ACM0002.
Monitoring frequency	As per ACM0002.
QA/QC procedures	As per ACM0002.
Any comment	-

Data/Parameter	Headwater level
Data unit	m
Description	Headwater level
Source of data	Operations data log at project site. Measured at head water entering generating unit.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	Hourly
QA/QC procedures	The monitoring system used by the DSS will gather and archive this data. The data acquisition system used for the Decision Support Tool will provide highly accurate data. Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Data/Parameter	Tail water level
Data unit	m
Description	Tail water level
Source of data	Operations data log at project site. Measured at tail water leaving generation units.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	Hourly
QA/QC procedures	The monitoring system used by the DSS will gather and archive this data. The data acquisition system used for the Decision Support Tool will provide highly accurate data. Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Data/Parameter	$EG_{hpu,h}$
Data unit	MWh
Description	Observed power output of 'hpu' unit for week 'x'.
Source of data	Operations data log available at the project site.
Measurement procedures (if any)	Hourly data records for each power generating unit in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	Hourly
QA/QC procedures	Meters shall be tested annually and calibrated as recommended by the manufacturer. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Data/Parameter	N
Data unit	Units
Description	Total number of hydro power generation units 'hpu' within the project site on the same water course.
Source of data	Project site.
Measurement procedures (if any)	Count the number of hydro power generation units within the project site on the same water course. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	M
Data unit	Units
Description	Total number of spillways within the project site on the same water course.
Source of data	Project site.
Measurement procedures (if any)	Count the number of spillways within the project site on the same water course. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	a_i, b_i, c_i and d_i
Data unit	Units
Description	The power polynomial coefficients for each generating unit based on "Hill Diagram" information provided by the owner or manufacturer. The "Hill Diagram" defines the three dimensional relationship between power output, head and flow.
Source of data	Manufacturer/owner
Measurement procedures (if any)	A 'hill diagram' will be included in the data book for every generating unit in the project boundary. This essentially provides information derived in equations 2.
Monitoring frequency	This shall be checked yearly and compared with baseline data. Hill Diagrams for a generating unit are stationary and do not change measurably within the life of the project. Any changes, however unlikely, would be in the direction of deterioration of the unit and would make the results of the project more conservative (i.e. yield lower generation in project years).
QA/QC procedures	-
Any comment	-

Data/Parameter	C_o
Data unit	Units
Description	Known coefficient taken from manufacturer/owner data.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	The equation given by the owner will provide accurate data.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	L_e
Data unit	m
Description	Length of the gate measured as built.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	The equation given by the owner will provide accurate data.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	O
Data unit	m
Description	Vertical opening.
Source of data	Measured during operations at the project site.
Measurement procedures (if any)	Hourly data records for each spillway in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	Hourly
QA/QC procedures	These measurements are very simple to make and accurate. More importantly the measurements will be completely consistent between the baseline year and the project year. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Data/Parameter	E_{sill}
Data unit	m
Description	Elevation of the sill measured as built.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	The equation given by the owner will provide accurate data.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	E
Data unit	Units
Description	Known coefficient taken from manufacturer/owner data.
Source of data	Manufacturer/owner data, design and or testing information for spillway.
Measurement procedures (if any)	The equation given by the owner will provide accurate data.
Monitoring frequency	This shall be checked yearly and compared with baseline data.
QA/QC procedures	-
Any comment	-

Data/Parameter	WL_h
Data unit	m
Description	Water level in week 'x'.
Source of data	Operations data log at project site.
Measurement procedures (if any)	Hourly data records for each spillway in the project boundary from the year previous to the implementation of the project activity shall be used to characterize the baseline scenario. The data shall be stored until two years after the end of the crediting period.
Monitoring frequency	Hourly
QA/QC procedures	Meters shall be tested annually and calibrated as recommended by the manufacturer. Meters are typically accurate to plus or minus a tenth or hundredth of a percent. All measurements should use calibrated measurement equipment that is maintained regularly and checked for its functioning.
Any comment	-

Annex I: Estimation process for standard error (SE)

The estimated value of $EG^{Bl}{}_{,x}$ is

$$EG_x^{Bl} = f(Q_x^{Pr}) = a + b_1 Q_x^{Pr} + b_2 (Q_x^{Pr})^2 + ... + b_n (Q_x^{Pr})^n \quad (1)$$

In the event that there is only one year in the baseline period, the methodology noted in Section A below will be implemented to determine the standard error of estimate. In the event that two or more years are available, the methodology in Section B below will be implemented.

(A) Methodology for Baseline Period = 1 Year

(I) If the equation is linear, i.e., n=1.

$$SE(EG_x^{Bl}) = \bar{\sigma} * \sqrt{(1 + \frac{1}{N} + \frac{(Q_x^{Pr} - \bar{Q})^2}{\sum_i^N (Q_x - \bar{Q})^2})} \quad (2)$$

Where:

σ = is the estimated standard error of the equation. This is reported by the software used to estimate the relationship between power generation and the flow. It can also be estimated as follows:

$$\bar{\sigma} = \frac{1}{N-2} * \sqrt{(1 - R^2) * (\sum_{i=1}^N (EGx - \bar{EG})^2}$$

$$\bar{EG} = \frac{\sum_{i=1}^N EG_x}{N} \quad (3)$$

N = is the total number of observations used in estimating the power generation v/s flow equation. It will be 54 if one full years data is used, without any week being dropped of because of unusual circumstances.

EG_i = is the baseline data that was used to estimate the equation form.

$$\bar{Q} = \frac{\sum_{i=1}^N Q_x}{N} \quad (4)$$

Similarly Q_x is the flow data in the baseline used to estimated the Equation (1).

(II) If n>1

$$SE(EB_{Bl,x}) = \bar{\sigma} * (1 + [QX]' \{[QI]'[QI]\} [QX]) \quad (5)$$

[QX] = is (nx1) vector $[Q_i, (Q_i)^2, ..., (Q_i)^n]$ is vector (1xn) of variables for observation of flow in the power equation, where n is the degree of polynomial.

$$[QX]' = \begin{bmatrix} Q_i \\ Q_i^{\ 2} \\ . \\ . \\ Q_i^{\ n} \end{bmatrix}$$ is (nx1) vector transpose of [QX].

$$[QI] = \begin{bmatrix} Q_1 & Q_1^{\ 2} & & Q_1^{\ n} \\ Q_2 & Q_2^{\ 2} & & Q_2^{\ n} \\ . & & & . \\ . & & & . \\ Q_N & Q_N^{\ 2} & & Q_N^{\ n} \end{bmatrix}$$ is the (Nxn) matrix of baseline flow observations, where N is

total number of observations and n is the degree of polynomial.

$$[QI] = \begin{bmatrix} Q_1 & Q_2 & & Q_N \\ Q_1^{\ 2} & Q_2^{\ 2} & & Q_N^{\ 2} \\ . & & & . \\ . & & & . \\ Q_1^{\ n} & Q_2^{\ n} & & Q_N^{\ n} \end{bmatrix}$$ is (nxN) transpose of [QI] matrix.

The Q_i represent the baseline flow data used to estimate the equation.