Jilamito Hydropower Project
Complementary Studies

Ecological Flow Analysis

Project # 0363579

Panamá City, November 3, 2016

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List of Acronyms

Acronym	Meaning in English
ERM	Environmental Resources Management
ESIA	Environmental and Social Impact Assessment
IIC	Inter-American Investment Corporation
IFC	International Finance Corporation
INGELSA	Investments in Electrical Generation, S.A.
masl	Meters above sea level
PS	Performance Standard (IFC)
ROR	Run-of-river
SERNA	Secretaria de Recursos Naturales y Ambiente

1 Executive Summary

Environmental Resources Management (ERM-Panama) has been asked to conduct an ecological flow assessment for the proposed run-of-river Jilamito Hydropower Project located within the Jilamito watershed. The assessment was conducted using hydrological statistical approach to determine low and ecological flows, flow exceedance curves and peak flows based on historical streamflow data collected by INGELSA since August 2005 up to July 2016. Due to the lack of continuous streamflow records at the proposed water intakes no.1 and no.2, ERM used the drainage-area ratio method to estimate daily streamflow values at those locations. Results from the hydrological statistical approach, and considering the Honduran ecological flow guidelines, the ecological flows that must be maintain at both locations of water intakes no. 1 and no.2 are greater than 0.21 m^3/s and 0.03 m^3/s, respectively. It is recommended that INGELSA continues monitoring streamflows during construction and operation phases of the Project. Also, the retention dams at both water intakes locations must include, in their final design, details of the hydraulic structures that will release an ecological flow equal or greater than 0.21 m^3/s and 0.03 m^3/s. Finally, ERM recommends that biannual monitoring campaigns should be conducted at the site by third-party, to ensure INGELSA continuously meets ecological flow guidelines at Jilamito River in the future.

2 Introduction

2.1 Background

INEGELSA is seeking financing from the Inter-American Investment Corporation (IIC) and the Multilateral Investment Fund (MIF or FOMIN) to develop a 14.9- Megawatts (MW) hydropower Project (HPP) on the Jilamito River in the Atlántida Department of northern Honduras (the Project). The Jilamito HPP is a run-of-the-river (ROR) hydropower project located within the Jilamito River watershed, approximately 37 kilometers (km) from the municipality of Tela and 130 km from San Pedro Sula, Honduras. Jilamito River is part of the Lean River watershed. According to the Honduran hydrologic map, the Lean River watershed occupies a total area of approximately 60 square kilometers (km^2) and it is considered under code number 5 of national importance.

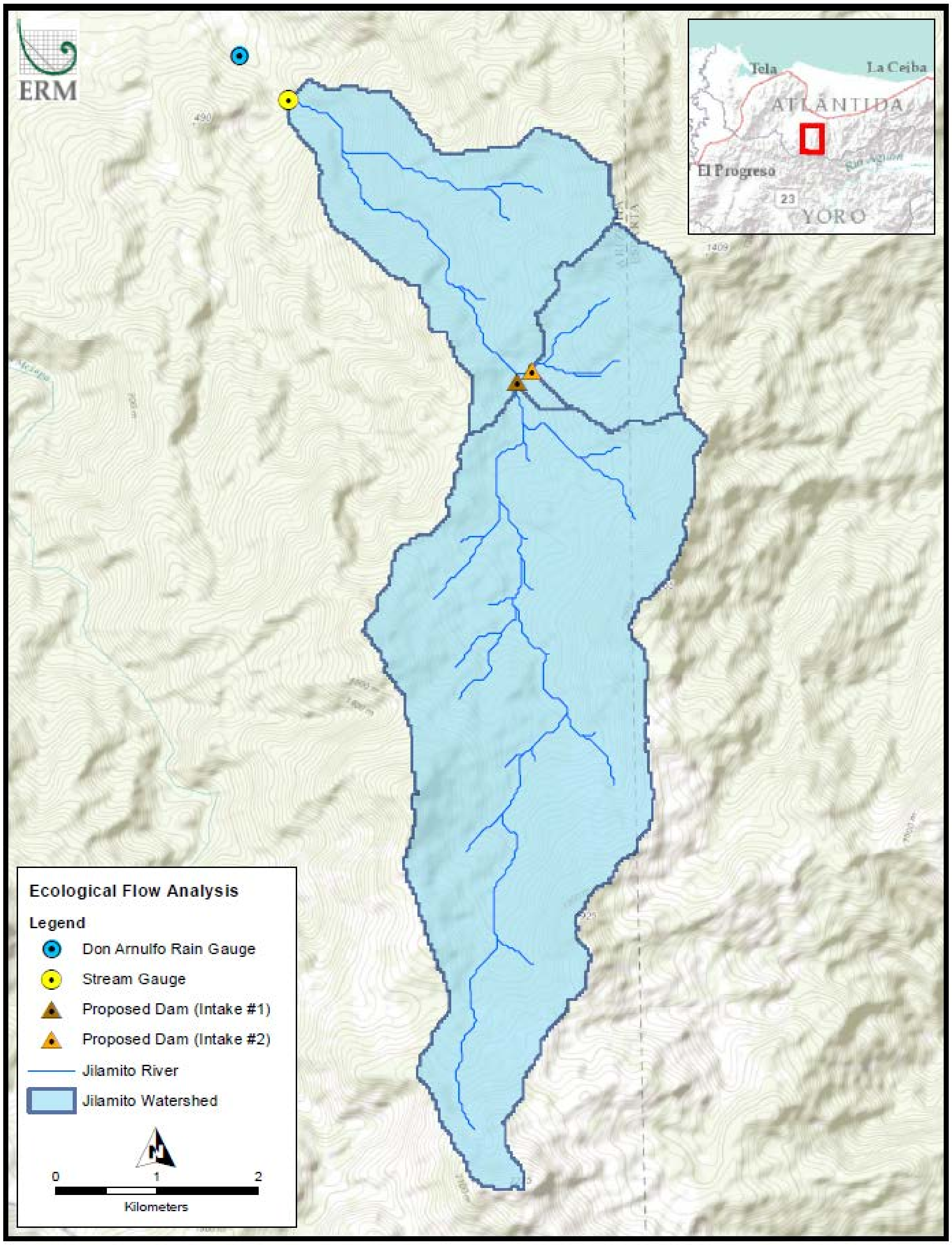
INGELSA has contracted Environmental Resources Management (ERM) to develop additional studies for the Project in order to provide the IIC with responses to outstanding questions regarding the compliance of the Project with the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability (PS). ERM's scope of services includes an ecological flow analysis using hydrological statistical methods.

The Jilamito River's catchment area at the proposed site is approximately 17.72 km^2 and at the streamflow gauge is approximately 21.98 km^2. Figure 2-1 shows the delineated watersheds at the streamflow gauge and the proposed water intakes. ERM delineated the subwatersheds at the proposed water intakes to estimate catchments areas at both proposed water intakes resulting on 14.48 km^2 and 2.18 km^2 for Intake No. 1 and Intake No.2, respectively. The Project is located in an area that receives an average annual precipitation of 5085 millimeters (mm), based on records from the rain gauge installed by INGELSA from August 2005 to July 2016 (see Figure 2-2). According to INGELSA (2013), the run-of-river (ROR) Jilamito HPP includes a design flood hydrograph of 340 m^3/s designed for a return period of 200-year (see Figure 2-3 and Figure 2-4). Other components of the proposed Project include:

- Two intakes over the streamflow
- 1,200-m conveying canal at the left bank of Jilamito River
- 2,400-m of penstock to conduct water from intake No. 1 to the powerhouse
- A power house

Figure 2-3 and Figure 2-4 show the location and profiles of the two proposed water intakes for the Jilamito HPP. As shown in Figure 2-3, a maximum of 0.50 m^3/s will be taken from the Jilamito Creek (Quebrada Jilamito) at intake no. 1 and conveyed into Jilamito River upstream of the proposed intake no. 1 through a 218.6-m long pipe. According to INGELSA and Lombardi (2015), the Jilamito Creek (Quebrada Jilamito or Dante) has a catchment area of aproximately 1.8 km^2 with average, maximum and minimum streamflow values estimated in 0.33 m^3/s, 0.08 m^3/s, and 1.96 m^3/s, respectevely. However, ERM redelineated the Jilamito Creek watershed at the proposed location of intake no. 2 and the catchment area was estimated in approximately

2.18 km^2 (see Figure 2-1). Watersheds shown in Figure 2-1were delineated by using a 30-meters digital terrain model (DTM)[1] from USGS and the Watershed Modeling System (WMS)[2].



Source: ERM 2016

Figure 2-1: Jilamito River Catchment Areas at the Streamflow and Proposed Water Intakes

[1] http://earthexplorer.usgs.gov/

[2] http://www.aquaveo.com/software/wms-watershed-modeling-system-introduction

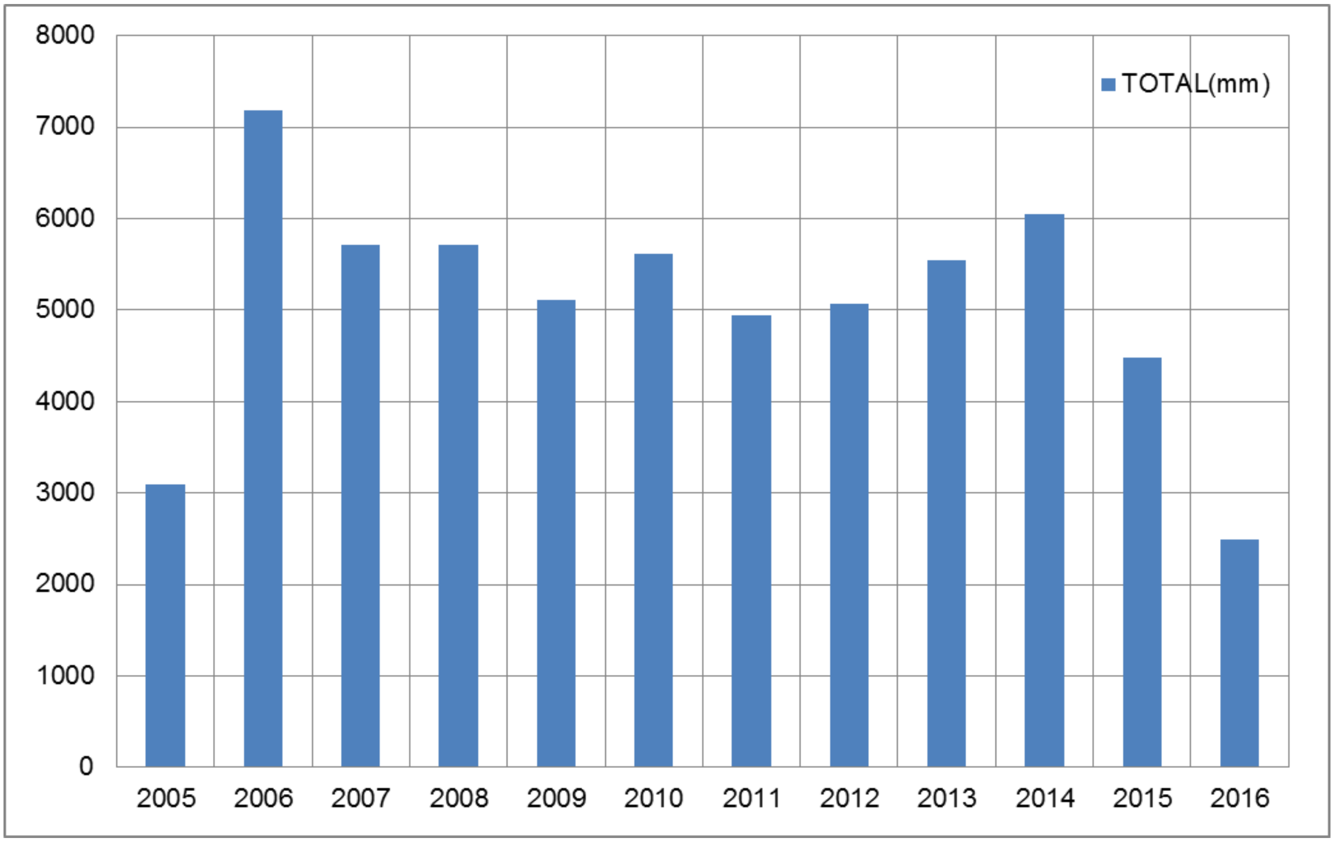
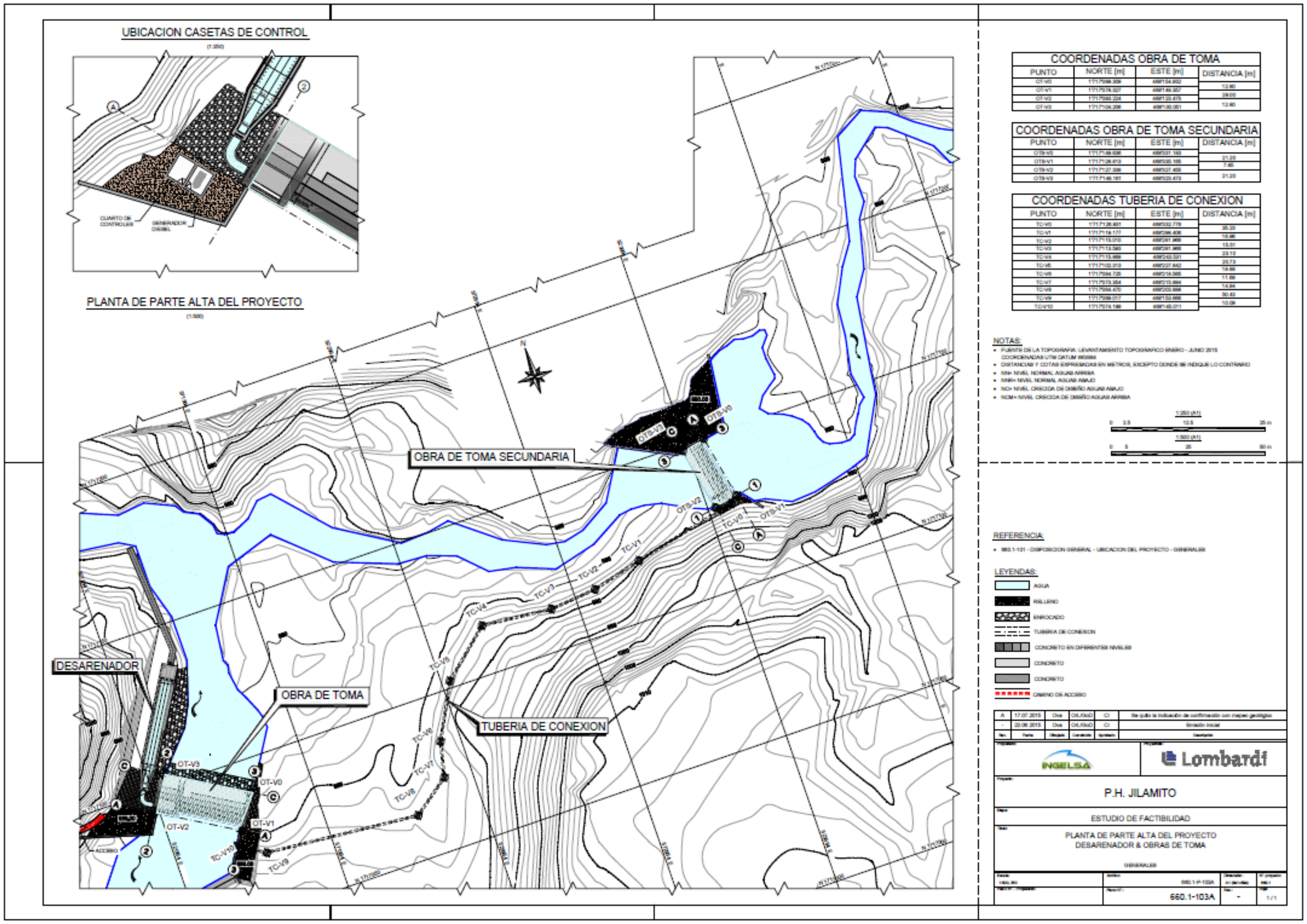
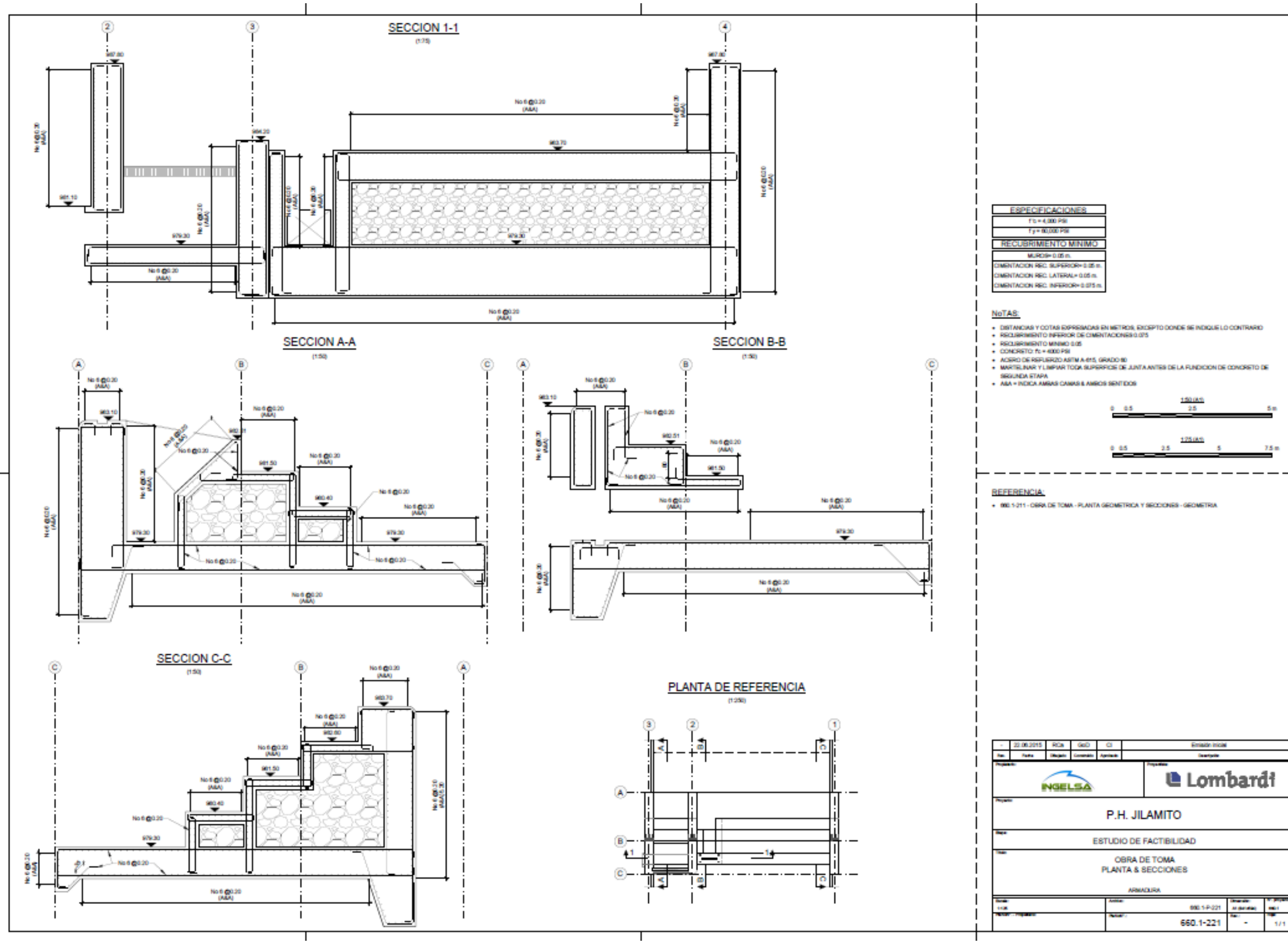


Figure 2-2: Historical Precipitation Records Measured at the Don Arnulfo Rain Gauge



Source: INGELSA and LOMBARDI, 2016

Figure 2-3: Top-view of the Jilamito HPP Intakes



Source: INGELSA and LOMBARDI, 2016

Figure 2-4: Intake Design Blueprint

Ecological flow (Qeco) in a river is defined as the minimum water needed to protect ecolological values at the watercourse. The main components of ecological flows are:

- quantity;
- frequency;
- duration;
- predictability;
- rate of variability/fluctuation

Changes in any of these five components can produce a significant impact on the ecological integrity of a given habitat because all of these components are regulators of ecological processes. To evaluate ecological flow at a given stream, an ecological flow assessment should be conducted. This ecological flow assessment is an evaluation of how much of the original flow regime of a river should continue to flow down it to maitain specified, valued features of the ecosystem hydrological regimes for the rivers, the environmental flow requiremetns, each linked to a predetermined objective in terms of the ecosystem's future condition (Kimura de Freitas, 2008). There are four main methods (hydrologic, hydraulic rating, habitat simulation or holistic) used to conduct ecological flows assessment in rivers and their selection is based on advantages and disadvantages of each method, and fitting tools and approaches to each situation. ERM used hydrological tools to evaluate ecological flow for the Jilamito HPP by considering the objectives established by IIC and Project's design and INGELSA's funds to support this ecological flow asessment.

Hydrological tools to determine ecological flow primarly use hydrological data (historical daily streamflow records) for making ecological flow recommendations for maintaining river health at designated level. This method is a simple, rapid, desktop approach that synthesizes two primary sources of information: 1) a hydrological analysis tool that is capable of assessing a range of flow levels; and 2) a literature review of the linkages between the flow regime and key riverine sources. Its ouputs could be considered simplistic, inflexible and low resultion but the method is suitable for low controversy situations such as the Jilamito Project which is a ROR hydropower Project (Kimura de Freitas, 2008).

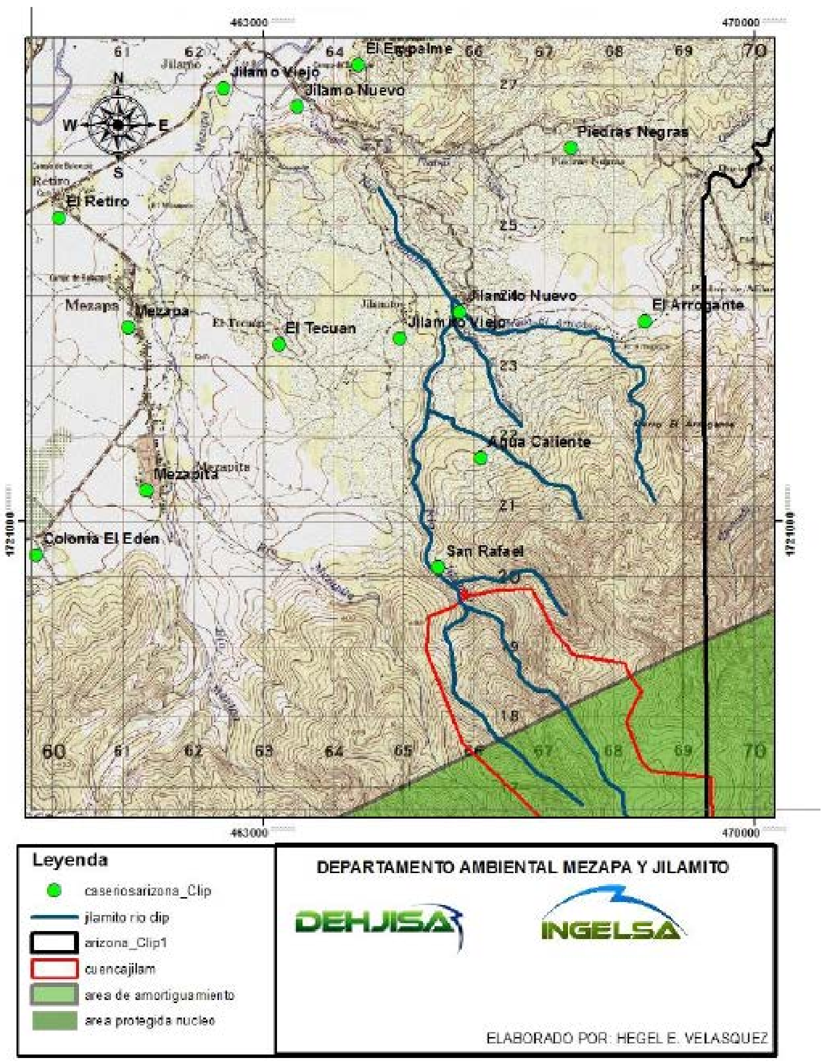
In recent years, ROR hydropower projects have emerged as a viable, low-impact alternative to existing large-scale projects. These ROR hydropower facilities use conventional hydropower technology to produce electricity by diverting river flow through turbines that spin generators before these waters are back to the river downstream of the intake structure. Among other advantages, the ROR projects avoid the need to build large dams to store water that can produce impacts on water quality such as anoxic deep waters and retention of sediments (REW, 2016). The absence of large reservoirs and dams considerably limits the social and environmental impacts of ROR projects, because the river is not converted into a reservoir. Therefore, the need for communities to relocate is avoided, and the effects on riparian and aquatic ecosystems are mitigated if adequate ecological flow is maintained. It is important to mention that mitigated effects should not be mistaken with avoided effects. According to

Helston (2016), any diversion of natural river flows causes changes in how the aquatic system works. In other words, the smaller the diversion of water, the gentler the impact.

2.2 Specific Objectives for Ecological Flow

The general objectives of this report are to provide the IIC with a well-grounded argument for the Project's compliance related to:

- Determine if the Project will affect other water users downstream (see Figure 2-4) of the Proposed Site;
- Describe flows during shortage of water by using droughts events for 10-, 25-, 50- and 100-year; and
- Provide recommendations for additional measures to prevent environmental impacts due to changes on downstream flows.



Source: INGELSA, 2016

Figure 2-5: Communities Located Near Jilamito HPP

3 Regulatory Framework

The Honduran Water Law (Ley General de Aguas) emphasizes the importance of preserving water availability without affecting water quantity and/or quality for other water users (DORH, 2009). The Natural Resources and Environment Secretariat (SERNA) establishes that all hydropower projects in Honduras must conserve and meet the ecological flow of 10% of the annual average flow even during the dry season in order to conserve the natural downstream aquatic and terrestrial ecosystems.

4 Methodology

ERM conducted a site visit on August 2016 where the ERM team was accompanied by INGELSA staff. During this visit, the ERM team was able to visit the study area (see Figure 2-3) and facilities of the Mezapa Hydropower Plant that is currently operating (see Figure 4-1). ERM team visited the Mezapa Hydropower Plant because the proposed Jilamito HPP will present similar hydraulic facilities and operating conditions to Mezapa HPP. Figure 4-2 and Figure 4-3 show the two main locations related to ecological flow aspects described in this report. Figure 4-2 shows the location of the stream gauge on Jilamito River while Figure 4-3 shows the location of the proposed site where the Jilamito HPP will be built.

Source: ERM August 2016

Figure 4-1: Mezapa Hydropower Operating Project

Source: Max Ayala March 2016

Figure 4-2: Jilamito River at the Streamflow Gauge

Source: Max Ayala March 2016

Figure 4-3: Jilamito River at the Proposed Site for the Hydropower Project

During the site visit, INGELSA staff explained to the ERM team that there are no continuous streamflow gauge data available in the Jilamito River at the proposed intakes sites. However, the historical available streamflow records have been collected downstream of the proposed site since October 2005. Figure 2-1 shows locations of the proposed water intakes and the streamflow gauge used to conduct hydrological statistics in this study. Based on these data, ERM used the drainage-area ratio method described by USGS (2008) to estimate the statistical flows at both proposed water intakes (ungauged). This method is often used when the ungauged site is on the same stream, upstream or downstream, of the gauged site and it is generally reliable only if the ungauged site is close to the gauged site and it is based on the assumption that the unit area runoff of the ungauged watershed is the same as that for the gauged site. The equation used in this method is as follows:

$$Q_u = \left[\frac{DA_u}{DA_g}\right] * Q_g$$

Where:

Q_u = Flow of the ungaged site

DA_u= Drainage area of the ungaged site

DA_g= Drainage area of the gaged site (Jilamito streamflow gauge; and

Q_g= Flow of the gauged site (water intake no.1 and water intake no.2)

Ecological and flood flow information is derived from the following sources:

Flow exceedance curves. These curves show the percent of days a particular flow was exceeded in the river at Jilamito streamflow gauge and at the proposed water intakes.

10 percent flows. These should not be confused with the flow exceedance percentage. The Honduran guidance for minimum flow is 10 percent of the mean annual flow.

Low flow statistics. Gauge data were fitted to a log-Pearson Type III distribution to generate low flow values. The results are in the form of duration-Q-frequency curves. For example, the 7Q10 statistic is the 7-day duration low flow with a 10 percent probability of occurring in any year while the 7Q2 statistic is the 7-day duration low flow with a 2 percent probability of occurring in any year.

Peak flow statistics. Similar to the low flow calculation, peak or flood flow statistics are shown to characterize flood flows, such as the 2-year (50 percent probability in any year) event that tends to define the bank-full event. The bank-full event is the flow that fills the main channel in most streams.

These hydrologic metrics are reported for the Project site and for the streamflow gauge. The period of streamflow data available for the Jilamito River and provided by INGELSA covers from October 2005 to August 2016. Results of the hydrologic metrics are described in section 5 below.

5 Results

5.1 Historical Records

Figure 5-1 shows the available streamflow data for Jilamito River collected by INGELSA since October 2005. Figure 5-2 and Figure 5-3 show the streamflow hydrographs created with the available historical streamflow records collected from the Jilamito streamflow gauge and estimated with the drainage-area ratio method for both proposed water intakes shown in Figure 2-1. The average streamflow records are 3.10 m^3/s, 2.04 m^3/s, and 0.31 m^3/s at the gauge, at intake no. 1 and intake no. 2, respectevily. Minimum and maximum streamflow records measured at the streamflow gauge are 0.91 m^3/s and 29.56 m^3/s. Therefore, minimum and maximum streamflow values estimated at the water intake no. 1 are 0.60 m^3/s and 19.48 m^3/s, respectevily; while minimum and maximum stremflow values estimated at the water intake no. 2 are 0.09 m^3/s and 2.93 m^3/s. Then, ERM used these data to conduct statistical analysis of ecological flow and floods for both sites as described below.

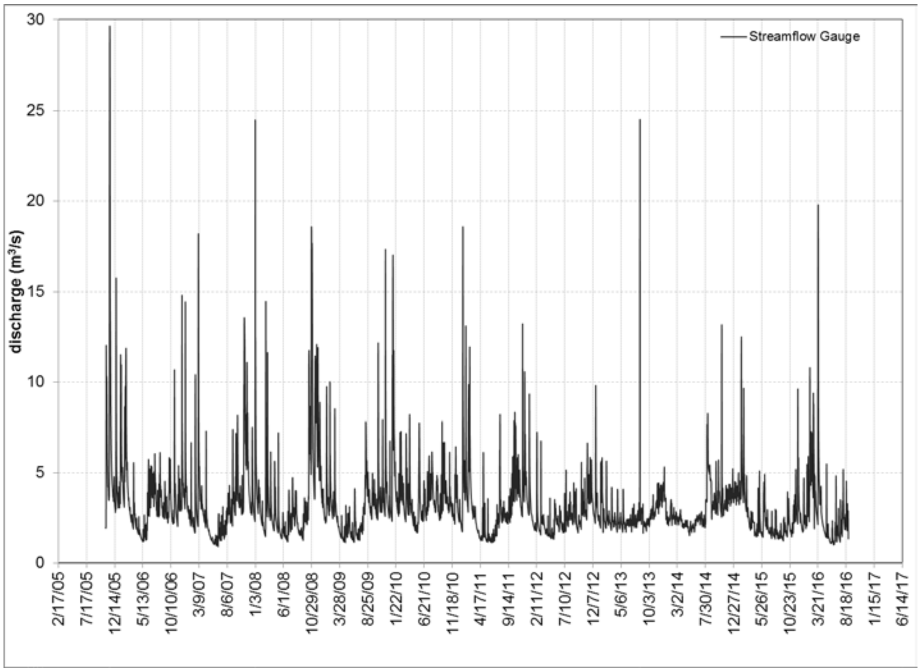


Figure 5-1: Hydrograph for Jilamito River at the Streamflow Gauge

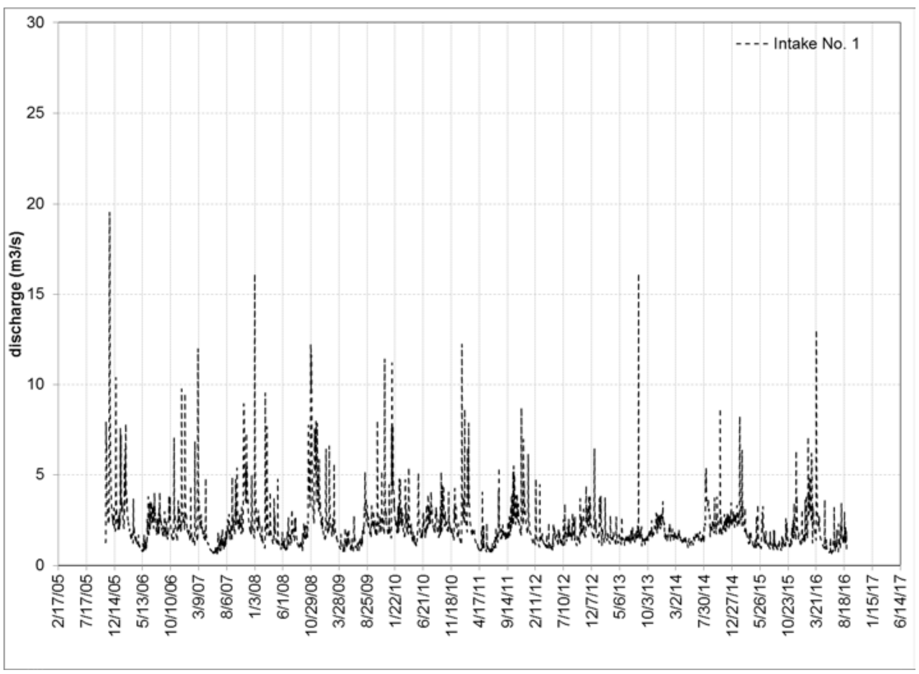


Figure 5-2: Hydrograph for Jilamito River at Intake No. 1

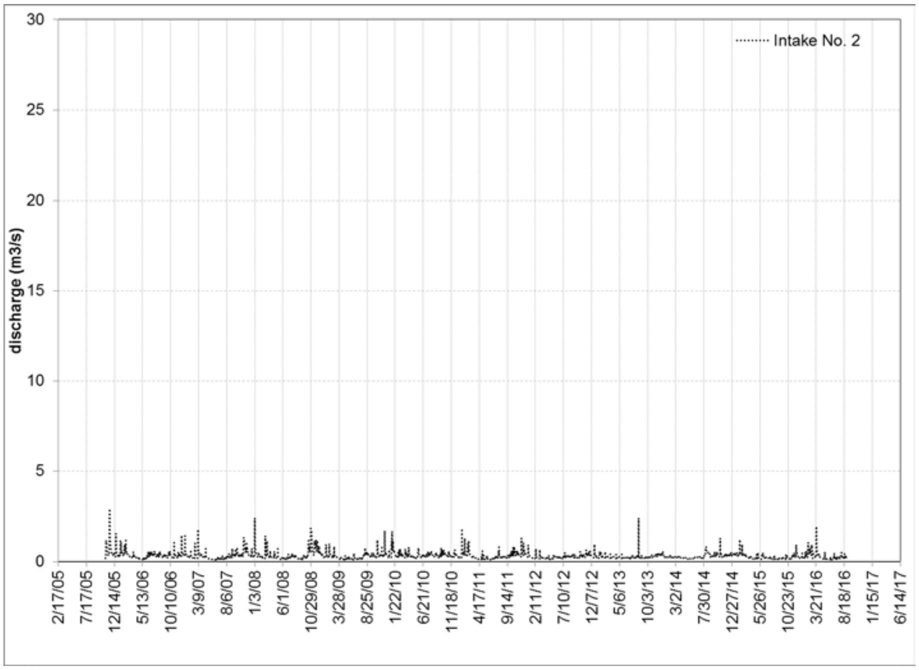


Figure 5-3: Hydrograph for Jilamito River at Intake No. 2

5.2 Low and Ecological Flows

Table 2-1 and Table 2-2 show the low and ecological flow statistics for the Jilamito gauge and the proposed dam site, respectively.

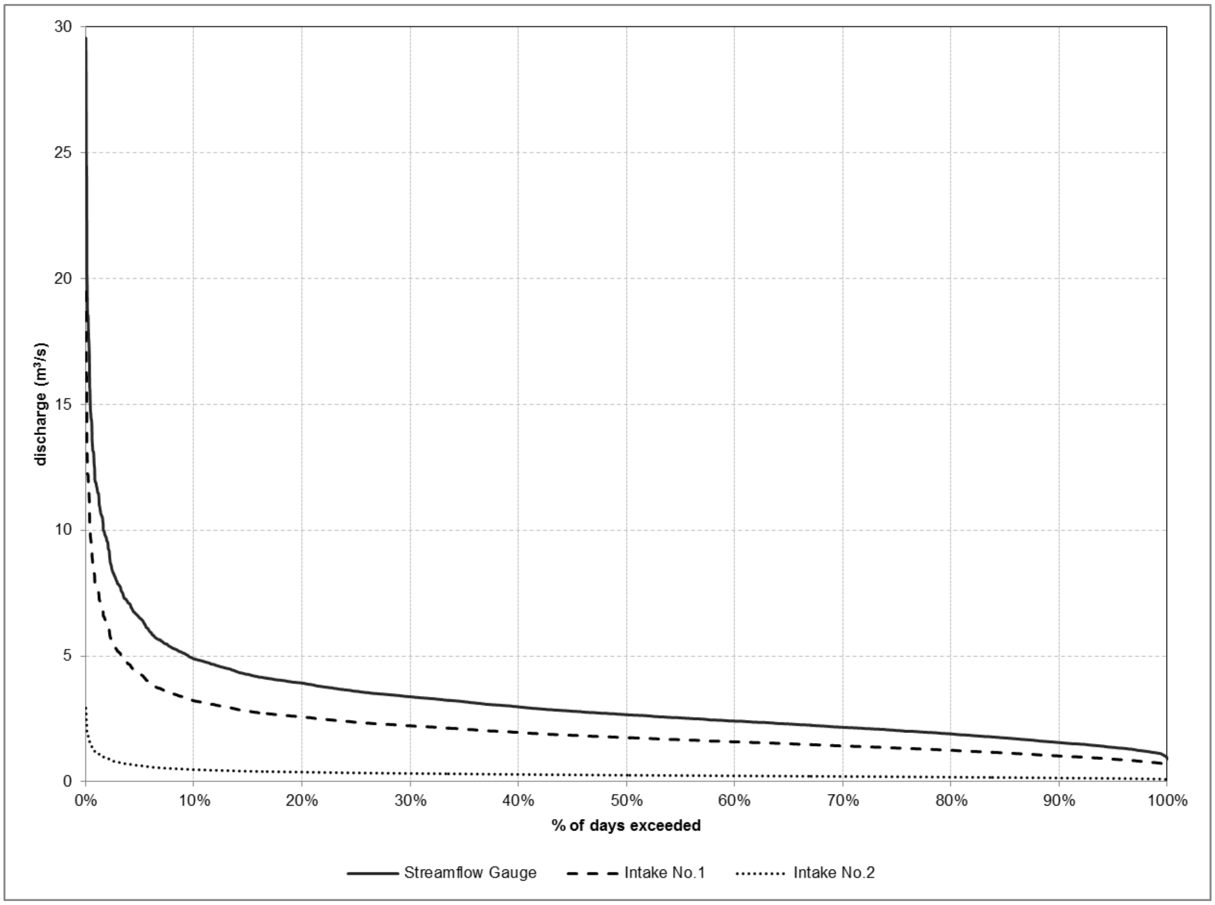
Table 5-1: Jilamito HPP - Ecological Flow Summary (all flows in m^3/s)

Parameter	Gauge	At Jilamito Gauge Site	At the Proposed Intake No. 1	At the Proposed Intake No. 2
	Drainage area (km^2)	**21.98**	**14.48**	**2.18**
Flow exceedance curve (one day flows)	90%	1.56	1.03	0.15
	95%	1.37	0.90	0.14
	50%	2.67	1.76	0.26
Statistical low flows	1Q2	1.28	0.84	0.14
	1Q5	1.56	1.03	0.18
	1Q10	1.73	1.14	0.21
	1Q25	1.95	1.28	0.25
	1Q50	2.11	1.39	0.28
	1Q100	2.11	1.49	0.32
	7Q2	1.42	0.94	0.14
	7Q5	1.85	1.22	0.18
	7Q10	2.14	1.41	0.21
	7Q25	2.54	1.68	0.25
	7Q50	2.86	1.88	0.28
	7Q100	3.19	2.10	0.32
	Mean annual daily flow	3.16	2.08	0.31
	10% of mean annual daily flow	0.32	0.21	0.03

Source: ERM from INGELSA data

5.3 Flow Exceedance Curves

Figure 5-1 show the flow exceedance curves calculated for the Jilamito streamflow gauge and for both proposed water intakes. The flow exceedance values for a 90% of occurrence correspond to 1.56 m^3/s, 1.03 m^3/s and 0.15 m^3/s at the Jilamito streamflow gauge, intake no. 1 and intake no. 2, respectively.



Source: ERM from INGELSA data

Figure 5-4: Flow Exceedance Curves – Streamflow Gauge, at Intake No. 1 and Intake No. 2

5.4 Peak Flows

Table 2-3 shows the 2-year, 1-day peak flows that tend to define primary channel morphology. Field observations confirm what the stream gauge data report.

Table 5-2: Jilamito HPP – Peak Flows Summary (all flows in m^3/s)

	At Jilamito Gauge Site	At the Proposed Intake No. 1	At the Proposed Intake No. 2
Watershed area *(km^2)*	21.98	14.48	2.18
2-year, 1-day peak *(m^3/s)*	17.45	11.50	1.73
5-year, 1-day peak *(m^3/s)*	22.74	14.98	2.26
10-year, 1-day peak *(m^3/s)*	26.12	17.21	2.59
25-year, 1-day peak *(m^3/s)*	30.28	19.94	3.00
50-year, 1-day peak *(m^3/s)*	33.31	23.91	3.30
100-year, 1-day peak *(m^3/s)*	36.29	25.87	3.60

Source: ERM from INGELSA data

6 Conclusions and Recommendations

Based on the Project description provided by INGELSA and results obtained from the hydrologic statistical analysis, ERM concludes that if the ROR's Project maintains an ecological flow greater than 0.21 m^3/s at the proposed water intake no.1, and 0.03 m^3/s at the proposed water intake no.2, the impacts on downstream water users will be consider minor or insignificant. INGELSA is committed to preserving 10% of the average annual flow at all time to prevent any impacts to downstream water users and aquatic biodiversity. However, there are not communities or other water users who depend on the section of the Jilamito River that will be diverted (see *Jilamito Social Study* for more details). Also, there are several streams that flow into the river section derived for hydropower combined with the ecological flow to be discharged from the proposed hydraulic structure at the Project site. The natural morphology of the Jilamito River at the proposed site will prevent erosion impacts in the river.

ERM recommends the following actions to meet ecological flow criteria and prevent environmental impacts on downstream water users and/or aquatic habitats:

- Continue conducting monitoring activities downstream of the Jilamito HPP (streamflow, precipitation and water quality) during construction and operation phases of the Project;
- Report results to SERNA and lenders at least every six months of monitoring activities, including results of historical streamflow, precipitation and water quality records and their compliance with national and international environmental guidelines (e.g., IFC);
- Maintain a minimum flow from primary intake structure of 0.21 m^3/s and 0.030 m^3/s from the secondary intake structure;
- Implement the proposed structures downstream of the proposed dams (water intakes) in order to prevent river scouring and/or erosion.
- Include details of the hydraulic structures that will release the specified ecological flow in both of the proposed dams (no.1 and no. 2 shown in Figure 2-3).

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