

# Design Verification and Post-construction Feasibility Reassessment of Naubise Khola Micro Hydropower, Nepal

Saurab Subedi

Universal Engineering & Science College  
(Pokhara University)  
Kathmandu, Nepal  
saurabsubedi200@gmail.com

Namrata Khadka

Universal Engineering & Science College  
(Pokhara University)  
Rukum, Nepal  
khadkanamrata01@gmail.com

Roshan Kharel

Tula's Institute  
(Uttarakhand Technical University)  
Kathmandu, Nepal  
roshan.202006016@tulas.edu.in

**Abstract**—Micro Hydropower (MHP) systems, generating up to 100 kW, are a vital solution for rural electrification in Nepal given the country's favorable topography and hydrology. This study evaluates the technical, economic, environmental, and social feasibility of the Naubise Khola Micro Hydropower Project located in Dhading district, Nepal. Field survey data indicate a design discharge of 45.738 l/s, a gross head of 164.6 m and a net head of 155.50 m after accounting for pipe friction and minor losses. Civil structures intake, canal, forebay, trash rack, spillway and penstock were re-analyzed and sized using standard hydropower design formulas, and a single-jet Pelton turbine was selected based on the available head and flow. Financial appraisal using a 6% discount rate over a 15-year plant life yields a Net Present Value of NPR 1,733,182, a Benefit-Cost Ratio of 1.16-1.29, and a simple payback period of approximately 8.4 years (10.7 years discounted). The results confirm that the project is technically sound, economically viable, and environmentally sustainable, though it currently suffers from an absent weir, deteriorated wooden transmission poles, and inadequate maintenance. Design and management recommendations are proposed to improve performance and to guide similar rural micro-hydropower developments.

**Index Terms**—Micro-hydropower, feasibility study, Pelton turbine, net present value, rural electrification, Nepal.

## I. INTRODUCTION

Micro hydropower (MHP) plants, which typically generate up to 100 kW [1], play a critical role in Nepal's energy sector given the country's mountainous terrain, its more than 6,000 rivers and streams, and the limited reach of the national electricity grid in remote areas. In villages beyond grid coverage, communities largely depend on diesel generators or firewood, both of which are costly, unreliable, and environmentally damaging. As demonstrated in off-grid micro-hydro schemes worldwide [6], MHP offers a decentralized alternative that supports lighting, small agro-industries, irrigation, and extended operating hours for schools and health posts. However, high initial capital cost and limited technical expertise continue to constrain the sustainability and scalability of existing plants in Nepal.

The Naubise Khola Micro Hydropower Project, situated in Dhading district, was constructed to supply electricity to the local community, but no comprehensive post-construction evaluation of its technical, financial, and social performance has been carried out. Without such an

assessment, there is a risk of underperformance, inefficient resource use, and failure to meet community needs.

This study therefore assesses the post-construction feasibility of the Naubise Khola MHP against five specific, measurable objectives: (i) quantify the surveyed discharge and head against the original AEPC design basis, using field velocity, cross-section, and reduced-level survey data, to determine whether the civil and hydraulic design remains valid; (ii) estimate the achievable power output at the design flow and at 40% flow-exceedance, and compare both against the installed 39 kW capacity; (iii) compute the project's Net Present Value, Benefit-Cost Ratio, Internal Rate of Return, and payback period at a 6% discount rate over a 15-year plant life; (iv) identify and document, through site inspection and community interviews, the environmental and social impacts and operational deficiencies affecting current performance; and (v) propose optimally sized civil and electromechanical components (forebay, weir, penstock, turbine) where surveyed dimensions deviate from standard design criteria. The remainder of this paper is organized as follows: Section II reviews related feasibility studies; Section III describes the study area; Section IV presents the survey and design methodology; Section V reports the results and discussion; and Sections VI and VII present the conclusion and recommendations, respectively.

## II. LITERATURE REVIEW

Existing feasibility studies of micro-hydropower (MHP) converge on a common methodological core while differing in what they identify as the decisive factor for project success. Rumbayan and Rumbayan [2], studying rural electrification via micro-hydro in Lalumpe Village, Indonesia, and Kengne Signe et al. [4], in a case study of the KEMKEN scheme in Cameroon, both frame feasibility primarily as a design-and-financing problem: the former emphasizes combining hydrological, financial, and demand-data collection with technical design and cost minimization, while the latter argues that proper selection and sizing of civil and electromechanical components — rather than site hydrology alone — is usually the determining factor in maximizing plant output. Misbah et al. [3] and Archetti [5] instead foreground the hydraulic-matching problem: assessing the Oboi River site in East Halmahera Regency, Misbah et al. show that crossflow

turbines can outperform Pelton or Francis units at certain low-head, high-flow sites, while Archetti demonstrates, for a small domestic plant, that a well-designed Pelton turbine only maximizes energy extraction from low-discharge sources when all upstream components (intake, forebay, penstock) are properly proportioned — together indicating that turbine choice and component sizing must be evaluated jointly with site hydrology rather than in isolation. A second strand of the literature, more directly relevant to the present study, evaluates MHP performance after commissioning rather than at the planning stage. Bhandari et al. [10], assessing a 26 kW plant in the same Dhading district of Nepal, and Butchers et al. [11], surveying 17 Nepali MHP sites, both find that post-construction sustainability depends less on the original hydraulic design than on institutional factors — trained operators, scheduled maintenance, and community management — echoing the operational deficiencies (absent weir, untrained operators, poor upkeep) identified in the present survey. Joshi's systematic review [13] of MHP sustainability studies in Nepal corroborates this pattern across the wider literature but also notes that few studies combine a detailed post-construction technical design re-verification with financial and social reassessment of the same scheme. This study addresses that gap by integrating field-based hydraulic re-analysis, standard hydropower design formulas, and financial appraisal to reassess the Naubise Khola MHP after construction, extending the pre-construction feasibility approaches of [2]–[5] to an operating plant.

### III. STUDY AREA

The Naubise Khola MHP is located near Dobhan village, Naubise, in Dhading district, Nepal, at approximately 27°41'39.37"N, 85°08'51.63"E and an elevation of about 1,400 m above sea level, within a subtropical hilly climate zone. The scheme draws from the Gurdam Khola and Dhuseni Khola to supply an installed capacity of 39 kW to 326 beneficiary households.

The headrace conveying water from the intake to the forebay is approximately 1,367 m long, comprising 886 m of stone-masonry canal in cement mortar and 481 m of HDPE pipe, traversing hilly terrain that limited survey access to some reaches. The site is reached by a foot trail from the local settlement area, consistent with the access constraints typical of hill-based micro-hydropower schemes in Nepal.

### IV. METHODOLOGY

A field survey recorded the dimensions of existing civil structures, while a GPS-based alignment survey (SW Maps) was conducted along the headrace. Canal discharge was measured by the float method over 5, 10 and 15 m reaches. The surveyed flowing cross-section was  $0.35 \times 0.33$  m and the average corrected mean velocity was 0.396 m/s; hence  $Q=AV=0.045738$  m<sup>3</sup>/s (45.738 l/s). The full canal dimensions were  $0.35 \times 0.36$  m, with the 0.33 m flowing depth retained to account for freeboard under AEPC/civil-works guidance.

The float method was selected because it required no specialized equipment and was practical on the hilly, foot-trail-accessed headrace. Surface velocity was corrected to mean velocity using the conventional 0.85 coefficient for

masonry canals. Recognized uncertainty arises from float type, reach length and cross-sectional non-uniformity [15]; an uncertainty of approximately  $\pm 10$ –15% is therefore retained for the reported discharge.

Gross head, penstock length and pipe geometry were obtained from reduced levels at the penstock inlet and turbine. Net head was calculated as  $H_{net}=H-(h_f+h_i+h_o)$ , with Darcy-Weisbach friction loss and entrance/exit minor losses. For the reported 150-mm penstock and  $Q=45.738$  l/s, the corresponding velocity is 2.588 m/s; the friction loss over the full 216-m penstock (117 m + 99 m sections, as listed in the AEPC salient features) is 8.585 m for a Darcy friction factor  $f \approx 0.0175$ , with entrance and exit loss coefficients  $K_i=0.5$  and  $K_o=1.0$ .

$$H_{net} = H - (h_f + h_i + h_o), \quad h_f = f l v^2 / (2gD_{in}) \quad (1)$$

The forebay was checked using  $Q_f=2Q_d$  and a 3-minute detention time. Thus  $V_{storage}=Q_f t=16.47$  m<sup>3</sup>. The required plan area is  $A=V_{storage}/H_{total}$ . The recommended layout is reported in the results section; the storage-volume check is included there so that the adopted dimensions can be verified directly.

$$V_{storage} = Q_f \times t, \quad A = V_{storage} / H_{total} \quad (2)$$

The economic penstock diameter was cross-checked using USBR, Sarkaria and JNN empirical relations [14]. Wall thickness was checked using the internal-pressure relation and compared with the Pacific Gas & Electric and Bureau of Reclamation criteria. The single-jet Pelton turbine was sized using the empirical velocity-ratio and jet-ratio method of Baral [8].

$$V_j = C_v \sqrt{2gH}, \quad D = 60v' / (\pi N), \quad m = D/d \quad (3)$$

The weir in Table V is a recommended design rather than an as-built structure, using the Sustainable Energy Industry Development Project (SEIDP) Common Method to replace the existing sandbag diversion. All other civil design procedures, including the canal freeboard allowance, follow [7]–[9].

For transparency, the calculated penstock diameters are 92.1 mm (USBR), 112.3 mm (Sarkaria) and 12.1 mm (JNN), with 150 mm adopted. The JNN result should be treated cautiously because the reported relation appears sensitive to unit convention and should be checked against the original guideline before physical implementation.

$$Deco = 0.62 P^{0.35} / H^{0.65} \quad (Sarkaria) \quad (4)$$

Wall thickness was checked against the internal-pressure design relation, alongside the Pacific Gas & Electric ( $t = D/288$ ) and Bureau of Reclamation ( $t = (D+200)/400$ ) criteria:

$$t = PD / (2\sigma\eta) + \varepsilon \quad (5)$$

Wall thickness was checked from  $t=PD/(2\sigma\eta)+\varepsilon$ , with  $\eta=0.9$  and  $\varepsilon=0.15$  cm; the final adopted thickness is compared with the PG&E and Bureau of Reclamation criteria in Table VIII. The weir flooding head was calculated from the standard rearranged form  $HB=[Q/(2.95Cd b)]^{2/3}$ , using  $Q=0.0457$  m<sup>3</sup>/s,  $Cd=0.50$  and  $b=0.98$  m, giving  $HB \approx 0.10$  m and a recommended 0.90-m weir height.

$$HB = [Q / (2.95 \cdot Cd \cdot b)]^{2/3} \quad (6)$$

where  $C_d$  is the weir discharge coefficient (0.5 for a broad, sharp-edged weir) and  $b$  is the clear waterway width, with total barrier height taken as the sum of weir height and flooding head  $H_B$ . Demand-side performance was further characterized using the yearly load factor (energy produced  $\div$  peak demand  $\times$  8,760 h), plant capacity factor (average output  $\div$  installed capacity), and utilization factor (peak load  $\div$  installed capacity).

Financial viability was assessed using Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and simple/discounted payback period, using a 6% discount rate and a 15-year plant economic life, based on cost and tariff data provided by the Alternative Energy Promotion Centre (AEPCC):

$$NPV = \sum [(Bt - Ct) / (1 + r)^t] \quad (7)$$

## V. RESULTS AND DISCUSSION

Table I summarizes the key field-survey parameters used as the basis for design verification.

TABLE I. FIELD SURVEY DATA SUMMARY

| Parameter                          | Value                                   |
|------------------------------------|-----------------------------------------|
| Canal width $\times$ flowing depth | 0.35 $\times$ 0.33 m                    |
| Flow area, A                       | 0.1155 m <sup>2</sup>                   |
| Mean velocity, V                   | 0.396 m/s                               |
| Design discharge, Q=AV             | 0.045738 m <sup>3</sup> /s (45.738 l/s) |
| Gross head, H                      | 164.6 m                                 |
| Penstock length, L                 | 216 m                                   |
| Penstock diameter, D               | 150 mm                                  |
| Internal pipe pressure             | 6.8 kg/cm <sup>2</sup>                  |

### A. Hydraulic and Head Analysis

Using the recorded reduced levels, the gross head between the pipe inlet and turbine was found to be 164.6 m over the 216 m penstock length (117 m + 99 m sections). Applying the Darcy-Weisbach friction equation and minor-loss coefficients (Table II) with the confirmed 150 mm penstock diameter, the total head loss was calculated as 9.10 m, giving a net head of 155.50 m. This agrees closely with the AEPCC-reported design value of 155.35 m and lies just below the independent Mini-Grid Support Programme (MGSP) commissioning verification range of 155.8-159.5 m across part-load conditions (25-75% of rated flow), as expected for full-flow operation.

\*Darcy friction factor for the steel penstock, adopted from the AEPCC MGSP design sheet (roughness 0.1 mm);  $K_i = 0.5$  and  $K_o = 1.0$  are standard entrance and exit loss coefficients.

TABLE II. NET HEAD CALCULATION SUMMARY

| Parameter            | Value                      |
|----------------------|----------------------------|
| Gross head, H        | 164.6 m                    |
| Penstock length, L   | 216 m                      |
| Penstock diameter, D | 0.150 m                    |
| Discharge, Q         | 0.045738 m <sup>3</sup> /s |
| Penstock velocity, V | 2.588 m/s                  |
| Friction factor, f   | $\approx 0.0175^*$         |
| Friction loss, $h_f$ | 8.585 m                    |
| Entrance loss, $h_i$ | 0.171 m                    |
| Exit loss, $h_o$     | 0.341 m                    |
| Total head loss, h   | 9.097 m                    |

| Parameter               | Value     |
|-------------------------|-----------|
| Net head, $H_{net}=H-h$ | 155.503 m |

### B. Turbine Selection

A single-jet Pelton turbine was selected based on the available head and flow (Table III). At a design speed of 1,000 rpm (6 poles, 50 Hz) and a computed specific speed within the recommended range for Pelton units, the turbine is estimated to deliver approximately 56.38 kW, exceeding the AEPCC-commissioned design capacity of 39 kW. This margin suggests the existing electromechanical equipment has additional headroom that could support future load growth if the intake and canal conveyance are upgraded.

Flow-duration analysis of eleven months of AEPCC-recorded discharge (Fig. 1) shows that at 40% probability of exceedance, the corrected discharge is approximately 0.249 m<sup>3</sup>/s, corresponding to a theoretical power potential of about 233 kW. This substantially exceeds the plant's installed capacity, indicating unutilized wet-season flow that could support a future capacity expansion, subject to penstock and turbine sizing constraints.

The AEPCC-installed system uses a synchronous generator rated at 82.5 kVA, 1,500 rpm, and 230/400 V three-phase output, connected through a belt-drive transmission, consistent with the single-jet Pelton configuration analyzed here.

TABLE III. PELTON TURBINE DESIGN SUMMARY

| Parameter                 | Value              |
|---------------------------|--------------------|
| Jet velocity, $V_j$       | 54.13 m/s          |
| Peripheral velocity, $v'$ | 24.86 m/s          |
| Jet diameter, d           | 32.8 mm            |
| Wheel diameter, D         | 474.7 mm           |
| Number of buckets         | 22                 |
| Rotational speed (6-pole) | 1,000 rpm          |
| Power output, P           | 75.6 HP (56.38 kW) |

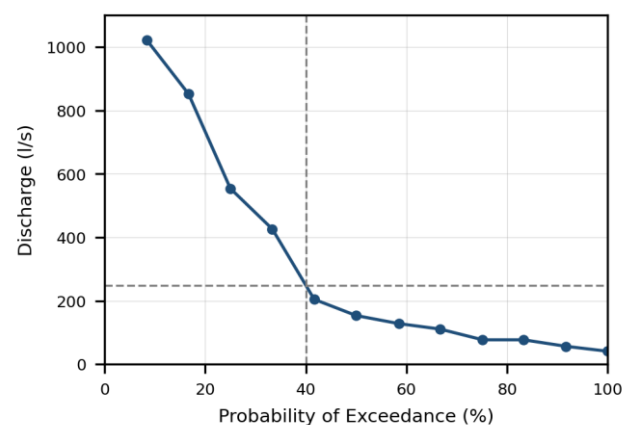


Fig. 1. Flow duration curve for Naubise Khola (11-month AEPCC record); 40% exceedance discharge  $\approx$  0.249 m<sup>3</sup>/s.

### C. Penstock, Forebay, and Weir Design

Table IV compares the economic penstock diameter obtained from the USBR, Sarkaria, and JNN empirical relations. The USBR and Sarkaria methods yield diameters of 92-112 mm, broadly consistent with the adopted 150 mm design diameter once a safety margin and available pipe sizes are considered; the JNN estimate is implausibly small

and likely reflects a unit-conversion simplification in the empirical relation, warranting verification against the original source formula. Fig. 2 illustrates the recommended forebay layout, giving a length of 5.79 m, width of 1.45 m, and total depth of 1.96 m — sized directly from the corrected 45.738 l/s design discharge and the adopted 150 mm penstock diameter (Section IV, eq. 2) — substantially larger than the 1.44 m × 1.40 m forebay currently in place (Table VIII), which supports the field observation that the existing forebay may be undersized. A direct storage check (Table VIII) confirms the recommended layout meets the 16.47 m<sup>3</sup> requirement exactly by construction. Table V summarizes the proposed weir dimensions, sized for a 45.7 l/s design discharge and a 0.98 m clear waterway width; a 1.00 m total barrier height is recommended in place of the current sandbag diversion.

TABLE IV. ECONOMIC PENSTOCK DIAMETER (COMPARISON OF METHODS)

| Method / check         | Calculated diameter |
|------------------------|---------------------|
| USBR (velocity-based)  | 92.1 mm             |
| Sarkaria (power-based) | 112.3 mm            |
| JNN (discharge-based)  | 12.1 mm†            |
| Adopted design         | 150 mm              |

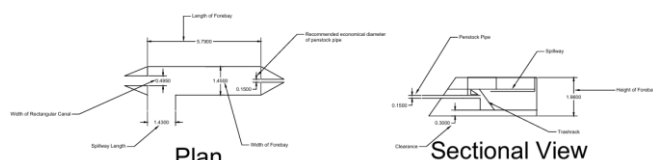


Fig. 2. Recommended forebay layout (plan and section view); L = 5.79 m, W = 1.45 m, D = 1.96 m.

TABLE V. WEIR DESIGN SUMMARY

| Parameter                 | Value                                   |
|---------------------------|-----------------------------------------|
| Design discharge, Q       | 45.7 l/s (0.0457 m <sup>3</sup> /s)     |
| Clear waterway width, b   | 0.98 m                                  |
| Discharge coefficient, Cd | 0.50                                    |
| Flooding head, HB         | ≈0.10 m                                 |
| Weir height, Hweir        | 0.90 m                                  |
| Total barrier height      | 1.00 m                                  |
| Basis                     | SEIDP Common Method; recommended design |

#### D. Load and Capacity Factors

Table VI summarizes demand-side performance indicators computed from AEPC load data, including the annual energy produced under each load category — 94,670 kWh for domestic and 53,820 kWh for business consumers — which underlies the load-factor calculation below. The domestic yearly load factor of 30.1% and business load factor of 19.2% are typical of rural MHP schemes where lighting dominates evening demand, while utilization factors above 80% for both categories indicate that peak demand approaches the plant's installed capacity. The overall plant capacity factor of 63.1% (Table VI) is computed from AEPC-metered average plant output (24.6 kW against the 39 kW installed capacity) rather than from the itemized committed loads above, so it reflects a somewhat broader usage base than the 94,670 + 53,820 kWh domestic-and-business total; it suggests moderate but

improvable use of the available generation capacity across the day.

TABLE VI. LOAD AND CAPACITY FACTORS

| Factor                       | Domestic           | Business |
|------------------------------|--------------------|----------|
| Yearly load factor           | 30.1%              | 19.2%    |
| Utilization factor           | 91.9%              | 82.1%    |
| Annual energy produced (kWh) | 94,670             | 53,820   |
| Plant capacity factor        | 63.1% (plant-wide) |          |

#### E. Financial Viability

Financial indicators computed at a 6% discount rate over a 15-year plant life (Table VII) confirm that the project is economically sound: NPV is positive (NPR 1,733,182 at a 6% discount rate over 15 years), both the conventional and modified Benefit-Cost ratios exceed unity, and the computed IRR of approximately 10.7% exceeds the assumed minimum attractive rate of return of 6%. The simple and discounted payback periods of approximately 8.4 and 10.7 years, respectively, reflect the high upfront civil and electromechanical cost typical of micro-hydropower development in hilly terrain and the modest early-year net cash flow while the bank loan is being serviced (Table VII-A), but remain within the plant's 15-year economic life. These results are broadly consistent with recent techno-economic assessments of Nepali micro-hydropower mini-grids, which likewise find community-managed schemes financially viable under AEPC subsidy structures despite high upfront civil costs [12].

The equity investment is complemented by a bank loan of NPR 2,513,372 at 16% interest, repaid over five years through an annual installment of NPR 767,607 (Table VII-A). Because this installment is comparable in magnitude to the plant's early-year net cash flow, maintaining reliable annual revenue collection — particularly from the productive end-uses discussed in Section V-D — is important to servicing the loan without straining household tariff payments.

More broadly, the total project cost of NPR 12,436,819 was financed through a blend of AEPC subsidy (NPR 4,875,000), the bank loan noted above, local government (DDC/VDC) contribution (NPR 1,500,000), and community equity/in-kind contribution (NPR 3,548,447). This multi-stakeholder financing structure is typical of rural MHP development in Nepal and distributes financial risk across government, financial-institution, and community sources.

AEPC's approved tariff for the scheme charges domestic lighting consumers NPR 2 per watt per month and productive business end-uses NPR 10 per kWh. Applied to the connected loads in Table VI, this yields an annual electricity-sales revenue of NPR 860,640 from domestic lighting and NPR 538,200 from business consumers, totaling NPR 1,398,840/year, which is the revenue basis used in the cash-flow calculation above.

TABLE VII. FINANCIAL INDICATORS (6% DISCOUNT RATE, 15-YEAR LIFE)

| Indicator         | Value         |
|-------------------|---------------|
| Equity investment | NPR 3,548,447 |
| Annual O&M cost   | NPR 522,105   |

| Indicator                         | Value         |
|-----------------------------------|---------------|
| NPV @ 6%, 15 yr                   | NPR 1,733,182 |
| Benefit-Cost ratio (conv. / mod.) | 1.16 / 1.29   |
| Internal Rate of Return           | ≈10.7%        |
| Simple payback period             | ≈8.4 years    |
| Discounted payback period         | ≈10.7 years   |

TABLE VII-A. LOAN AND REPAYMENT STRUCTURE

| Parameter          | Value         |
|--------------------|---------------|
| Bank loan amount   | NPR 2,513,372 |
| Interest rate      | 16%           |
| Repayment period   | 5 years       |
| Annual installment | NPR 767,607   |

### F. Field Observations and Design Comparison

Table VIII compares AEPC/survey values against the calculated design values, showing broad agreement in head and discharge but notable differences in the forebay and spillway sizing, reinforcing the finding in Section V-C that the constructed forebay may be undersized relative to standard detention-time criteria. Site inspection was combined with interviews with two local community members — the plant's caretaker and a shopkeeper located near the powerhouse — covering their first-hand observations of the plant's operation and condition; responses were audio-recorded, transcribed, and grouped by recurring issue category following a basic thematic-analysis approach, consistent with the operational deficiencies reported in comparable post-construction assessments of other Nepali MHP schemes [10], [11]. Six such recurring deficiencies were identified:

- No permanent weir — sandbags and stones are used to divert water into the canal.
- Deteriorating transmission infrastructure — most poles are timber rather than iron or RCC and rot quickly in the local climate.
- Poor maintenance — civil and electromechanical components receive little to no scheduled upkeep.
- No trained operator — the plant lacks dedicated, knowledgeable personnel for day-to-day management.
- Canal damage — sections are destroyed by landslides, and flow is frequently obstructed by fallen leaves and debris.
- Improvised trash racks — wood is used in place of steel trash racks at some canal sections.

\*Forebay L×B×H sized directly from  $Q_f=2Q_d$  and the 3-min detention criterion (eq. 2); L×B×H = 16.47 m<sup>3</sup> matches the required storage volume by construction.

†The JNN diameter is retained as reported but requires unit-convention verification.

TABLE VIII. COMPARISON OF AEPC/SURVEY AND CALCULATED VALUES

| Parameter                 | AEPC    | Calculated |
|---------------------------|---------|------------|
| Discharge (l/s)           | 42      | 45.7       |
| Power (kW)                | 39      | ≈56.4      |
| Gross head (m)            | 160     | 164.6      |
| Net head (m)              | 155.35  | 155.50     |
| Penstock dia./thick. (mm) | 156 / 4 | 150 / 2    |

| Parameter                                   | AEPC        | Calculated                    |
|---------------------------------------------|-------------|-------------------------------|
| Canal width (m)                             | 0.35        | 0.495                         |
| Forebay L×B×H (m)                           | 1.44×—×1.40 | 5.79×1.45×1.96                |
| Spillway length (m)                         | 0.62        | 1.43                          |
| Weir                                        | None        | 2×1×0.9 m proposed            |
| Forebay storage check ( $Q_f=2Q_d$ , 3 min) | —           | 16.47 m <sup>3</sup> required |
| Forebay volume from 5.79×1.45×1.96 m        | —           | 16.47 m <sup>3</sup>          |

### G. Environmental and Social Considerations

In accordance with national environmental screening guidelines for micro-hydropower projects, no significant adverse environmental impacts were identified; observed disturbances are limited to localized bank disturbance near the intake and minor sedimentation in the settling basin, both manageable through routine desilting. Socially, the scheme directly benefits an estimated 326 households (about 8.4 households per installed kW) and enables productive end-uses such as agro-milling, a saw mill, an oil expeller, a computer institute, and poultry farming. These productive loads account for roughly 17% of total electricity demand, indicating meaningful — though still expandable — use of the plant beyond domestic lighting.

### H. Institutional and Legal Considerations

The plant operates under a community-ownership model, consistent with AEPC's subsidy policy for rural electrification, and no land-tenure or legal disputes were reported since the intake and headrace alignment lie within community-managed land. Formalizing a local users' committee with clearly assigned responsibilities for tariff collection, fund management, and maintenance oversight building on the technical recommendations in Section VII would strengthen the institutional sustainability on which the technical and financial feasibility findings in Sections V-A to V-F ultimately depend.

## VI. CONCLUSION

The Naubise Khola Micro Hydropower Project is technically feasible, economically viable, and environmentally sustainable. Field-verified hydrological and topographical data confirm an adequate design discharge and head to support reliable power generation via a single-jet Pelton turbine, while NPV, BCR, and IRR indicators confirm the investment is financially sound over a 15-year operating horizon. However, the absence of a permanent weir, deteriorated wooden transmission infrastructure, and the lack of routine maintenance and trained personnel currently limit the plant's long-term performance and warrant priority attention.

This assessment is subject to the limitations of a short-duration field study: available hydrological records span only eleven months rather than a multi-year series, full dry- and wet-season variability could not be captured, the hilly terrain constrained access for inspecting some structures, and the social assessment draws on only two community interviews, so the reported deficiencies should be read as indicative rather than an exhaustive community survey. Multi-year flow monitoring and a broader stakeholder sample are recommended to refine the estimates presented here.

## VII. RECOMMENDATIONS

### A. Technical

- Construct a permanent concrete or gabion weir to replace the existing sandbag diversion and ensure consistent intake flow.
- Replace deteriorated wooden transmission poles with metal or RCC poles to improve durability.
- Install a steel trash rack and line the canal to reduce landslide- and debris-related blockage.
- Rebuild the forebay to the calculated design dimensions (Table VIII) to restore the intended 3-minute detention time.

### B. Economic and Financial

- Apply economic-diameter methods (USBR/Sarkaria) consistently during any future penstock replacement to minimize capital cost.
- Maintain reliable tariff collection to service the outstanding bank loan (Table VII-A) without disrupting O&M funding.
- Encourage productive end-use (agro-processing, irrigation) to raise the plant load factor and revenue.

### C. Environmental and Social

- Monitor sedimentation near the intake and settling basin and engage the community in operation and profit-sharing decisions.
- Train and appoint a dedicated local operator for routine maintenance and monitoring.

### D. Further Study and Monitoring

- Install flow and energy monitoring equipment and extend seasonal discharge records to support future capacity planning.
- Use this project as a case study for applying the same design-verification and financial-appraisal approach to nearby rural micro-hydropower schemes.

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