Environmental and Social Impact Assessment

PUBLIC

Document Stage: Draft
Project No: 58276-001
July 2026

Bhutan: Bunakha Green Power Development Project

Main Report

Prepared by Druk Green Power Corporation Limited for the Asian Development Bank.

This environmental and social impact assessment is a document of the borrower. The views expressed herein do not necessarily represent those of the Board of Directors, Management, or Staff of the Asian Development Bank (ADB), and may be preliminary in nature. Your attention is directed to the "terms of use" section of ADB's website.

In preparing any country program or strategy, financing any project, or by making any designation of or reference to a particular territory or geographic area in this document, ADB does not intend to make any judgments as to the legal or other status of any territory or area.

Draft

ESIA Report of Bunakha Hydropower Project

Table of Contents

1 Introduction 1

1.1 Authorization .....**Error! Bookmark not defined.**

1.2 The Project's Background 1

2 Policy, Legal and Institutional Framework.....2

2.1 National Policy and Strategic Framework 2

2.2 National Legal Framework.....4

2.3 National Institutional Framework 17

2.4 National Technical Guidelines 21

2.5 International Framework.....22

2.5.1 International conventions.....22

2.5.2 Asian Development Bank's Safeguard Policy Statement (2009).....25

2.6 Gap Analysis 32

2.7 Permits and Approvals 39

2.7.1 Approval of the ESIA report by NEC.....39

2.7.2 Process as per this ESIA and this Project 40

2.7.3 Procurement, agreements, and ESS integration.....40

2.8 Environmental Quality and Emission Standards Applicable to the Project 41

2.8.1 Applicable standards for air quality.....41

2.8.2 Applicable standards for noise.....42

2.8.3 Applicable standards for water quality 42

2.8.4 Applicable standards for soil quality 43

3 Project Description 45

3.1 Access 46

3.2 Type of Project 46

3.3 Hydropower projects within the Wangchhu River Basin.....47

3.3.1 Catchment Area Characteristics 48

3.4 Engineering Characteristics.....48

3.4.1 Dam 50

3.4.2 Mid-level Outlet 52

3.4.3 Bottom outlet.....52

3.4.4 Waterways (Head Race) 53

3.4.5 Powerhouse and Transformer Cavern 54
3.4.6 Tailrace Conduit 56
3.4.7 Tailrace outlet 56
3.4.8 Reservoir 57
3.4.9 Permanent structure for power generation 57
3.4.10 Tunnel and underground works 57
3.4.11 Additional residential buildings at CHP colony 59
3.4.12 Replacement of the bridge at the Chanachen farm road 59
3.5 Construction Phase 59
3.5.1 Pre-construction works 62
3.5.2 Main construction works 63
3.5.3 River diversion 64
3.5.4 Construction materials 65
3.5.5 Muck disposal (M-D) areas 66
3.5.6 Contractors' construction facilities (CCFs) 67
3.5.7 Construction water requirements 68
3.5.8 Construction power requirements 69
3.5.9 Workforce requirements during construction 69
3.5.10 ..... Transmission lines 73
3.6 Operational Phase 73
3.6.1 Workforce requirements during operation 75

4 Area of Influence 76
4.1 Background and Definitions 76
4.2 The Bunakha HPP's Area of Influence 77
4.2.1 Treatment of Induced Impacts 78
4.3 Interaction Hotspots 78

5 ESIA Scope, Objectives and Methodology 80
5.1 Methodology for Data Collection 80
5.1.1 Physical environment surveys methodology 81
5.1.2 Terrestrial biodiversity surveys methodology 90

5.1.3 Aquatic biodiversity surveys methodology 95
5.1.4 Socio-economic survey methodology 106
5.2 Methodology for Specialist Studies 109
5.2.1 Environmental flow assessment 109
5.2.2 Climate and Disaster Risk Assessment 113
5.2.3 Critical Habitat Screening 114
5.2.4 Critical Habitat Assessment (CHA) 117
5.2.5 Resettlement plan 119
5.3 Methodology for Assessment of the Significance of Impacts 120
5.3.1 Sensitivity 123
5.3.2 Magnitude 124
5.3.3 Significance 126
5.3.4 Assessment of cumulative impacts 126

6 Analysis of Alternatives 127
6.1 Location Selection 127
6.2 Description of the Initial Options 127
6.3 Analysis of Technologies and Design 130
6.4 Consideration of Environmental and Social Factors in Alternative Selection 131
6.5 “Without Project” Situation 132

7 Description of the Existing Environment 134
7.1 Physical Environment 134
7.1.1 Meteorology 134
7.1.2 Soil quality 135
7.1.3 Geological and geospatial aspects 135
7.1.4 Seismo-tectonics 141
7.1.5 Hydrology of the basin 142
7.1.6 Water resources 143
7.1.7 Water quality 144
7.1.8 Air quality 148
7.1.9 Noise 150
7.2 Biological Environment 151
7.2.1 Aquatic Biodiversity 151
7.2.2 Terrestrial Biodiversity 154

7.2.3 Protected and Conservation Areas 158
7.2.4 Ecosystem services 163
7.2.5 Critical habitats 167
7.3 Human Environment 171
7.3.1 Project districts/Dzongkhags 171
7.3.2 Project Gewogs 175
7.3.3 Project Chiwogs 176
7.3.4 Land use/ land cover 181
7.3.5 People 182
7.3.6 Material and economic assets 185
7.3.7 Tourism 187
7.3.8 Sensitive environmental receptors 187
7.3.9 Results of the Socio-economic survey 190

8 Important Environmental and Social Components 193
8.1 Sensitivity of the IESCs 198

9 Climate Impact Assessment 205
9.1 Greenhouse Gas Emission Reductions Associated with Implementing the Project 205
9.2 Compatibility of the Project with Bhutan's Carbon Neutral Policy 208
9.3 Impacts of Climate Change on the Project – Climate and Disaster Risk Assessment (CDRA) 208
9.3.1 Historical trend analysis 209
9.3.2 Climate change projections 218
9.3.3 Glacial lake outburst flood (GLOF) 243
9.3.4 Landslide dam outburst flood (LDOF) 245
9.4 Climate Change Risk Management Plan 246
9.4.1 Changes in streamflows and energy generation 246
9.4.2 Changes in floods (dam safety) 247
9.4.3 Impacts on GLOFs (dam safety) 247
9.4.4 Landslides and LDOFs (dam safety) 247
9.4.5 Sediment load 248

10 Environmental Impact Assessment 253
10.1 Step 1: Distinguish Positive and Negative Impacts 254

10.1.1 Positive impacts on the physical environment 254
10.1.2 Positive impacts on the biological environment 257
10.1.3 Enhancement measures for positive impacts....258
10.2 Step 2: Dismiss Non-Significant Impacts 258
10.3 Step 3 (a): Multi Criteria Analysis - Impacts and Mitigation Measures During Pre-Construction 258
10.3.1 Impacts on the physical environment 259
10.3.2 Impacts on the biological environment 264
10.4 Step 3 (b): Multi Criteria Analysis - Impacts and Mitigation Measures During Construction 268
10.4.1 Impacts on the physical environment 268
10.4.2 Impacts on the biological environment 277
10.5 Step 3 (c): Multi Criteria Analysis - Impacts and Mitigation Measures During Operation 284
10.5.1 Impacts on the physical environment 284
10.5.2 Impacts on the biological environment 288
10.6 Summary of the Environmental Impacts' Significance 293

11 Social Impact Assessment 297
11.1 Step 1: Distinguish Positive and Negative Impacts 298
11.1.1 Enhancement measures for positive impacts....300
11.2 Step 2: Dismiss Non-Significant Impacts 301
11.3 Step 3 (a): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Pre-Construction 302
11.3.1 IESC #13: Land and Assets 302
11.3.2 IESC #14: Occupational Health and Safety (OHS)....305
11.3.3 IESC #15: Community Health and Safety....309

11.3.4 IESC #16: Infrastructures 312
11.3.5 IESC #17: Cultural, Religious and Historical sites....313
11.4 Step 3 (b): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Construction 315
11.4.1 IESC #14: Occupational Health and Safety (OHS)....315
11.4.2 IESC #15: Community Health and Safety....319
11.4.3 IESC #16: Infrastructures 322
11.4.4 IESC #17: Cultural, Religious and Historical sites....324
11.5 Step 3 (c): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Operation 326
11.5.1 IESC #14: Occupational Health and Safety (OHS)....326
11.5.2 IESC #15: Community Health and Safety....328
11.5.3 IESC #17: Cultural, Religious and Historical sites....331
11.6 Summary of the Social Impacts' Significance 332

12 Cumulative Impact Assessment 336
12.1 Land Environment 337
12.2 Biological Environment 337
12.3 Socio-Economic Impacts 343
12.4 Minimum E-flow Impacts 345
12.5 Climate Change Impacts 348
12.6 Cumulative Operational Phase Impacts....348
12.7 Climate and Disaster Risk Assessment (CDRA) into the Cumulative Impact Assessment....349

13 Environmental and Social Management Plan 350
13.1 ESHS Roles and Responsibilities 350
13.1.1 Project developer - BHPL....351

13.1.2 Independent ESHS consultant 351
13.1.3 ..... Contractors 352
13.1.4 RP implementation consultant 353
13.2 Compilation of the ESMP - Pre-construction Phase 354
13.3 Compilation of the ESMP - Construction Phase 362
13.4 Compilation of the ESMP - Operation Phase 373
13.5 Sub-Management Plans 380
13.5.1 Catchment area treatment (CAT) plan 380
13.5.2 ..... Compensatory afforestation plan 389
13.5.3 Dam Safety Emergency Preparedness Plan 396
13.5.4 Biodiversity conservation & wildlife management plan 419
13.5.5 ..... Species rescue plan 421
13.5.6 ..... Greenbelt development plan 426
13.5.7 Fisheries conservation and management plan 427
13.5.8 Air quality and noise management plan 433
13.5.9 ..... Labor management plan 436
13.5.10 Alternative fuel and energy supply plan for worker camps 451
13.5.11 Soil conservation 454
13.5.12 and restoration and landscaping plan 458
13.5.13 Mitigation measures for downstream siltation 461
13.5.14 Waste water management plan 462
13.5.15 Surface water quality management plan 466
13.5.16 Sanitation and solid waste management plan 469
13.5.17 Public health delivery plan/human health management plan 473
13.5.18 Energy conservation measures plan 476

13.5.19 Environmental, Social, Health and Safety Management Plan 479
13.5.20 Decommissioning plan 500
13.5.21 Blasting operation plan.....505
13.5.22 Crusher and batching plant operation.....513
13.5.23 Quarry restoration plan 518
13.5.24 Muck disposal plan.....519
13.5.25 Cultural heritage management plan (CHMP).....526
13.5.26 E-flow Management plan.....538
13.5.27 Climate risk management plan 538
13.5.28 Cumulative impacts management plan.....539

14 Environmental and Social Monitoring Programme 540
14.1 Self-Monitoring and External Auditing.....540
14.2 Adaptive Management 541
14.3 Compilation of the ESMoP for the Bunakha HPP 541
14.3.1 ..... Compliance monitoring 542
14.3.2 ..... Effects monitoring 556

15 Environmental Valuation.....572
15.1 Benefits of Environmental Conservation and Protection in Bunakha HPP Area 573
15.2 Benefits from Bunakha Hydropower Project 574
15.3 Comparison of Benefits of Environmental Conservation and Bunakha HPP 575

16 Overall Findings, Conclusion and Recommendations.....577
16.1 Overall Findings 577
16.2 Conclusion 578
16.3 Recommendations 578

17 References.....580

List of Figures

Figure 1: The environmental clearance process in Bhutan 40
Figure 2: Location of the Bunakha HPP within Bhutan (the red polygon represents the Project's Area of Influence - see Chapter 4) 45
Figure 3: Cascade of Projects on river Wangchhu..... 48
Figure 4: General Layout of Bunakha HPP 50
Figure 5: The proposed Bunakha HPP's dam layout 52
Figure 6: Longitudinal profile of waterway 55
Figure 7: Bunakha HPP's reservoir at full reservoir level 57
Figure 8: Location of the project facilities 61
Figure 9: River diversion plan..... 65
Figure 10: Foreseen organizational structure of the BHPL during the peak-construction period of the BHPP 72
Figure 11: Foreseen organizational structure of the Project authority during the operation period of the Bunakha HPP 75
Figure 12: Overview of the Bunakha HPP's Area of Influence 79
Figure 13: Wind, air and noise sampling points (ANSP) within the Bunakha HPP' AoI - dry and wet seasons 85
Figure 14: Surface water (SW) sampling locations within the Bunakha HPP' AoI - dry, wet and post-monsoon seasons 86
Figure 15: Soil sampling points (SSP) within the Bunakha HPP's AoI - dry (SSP-1 to 4) and wet (SSP-5 to 8) seasons..... 87
Figure 16: Traffic surveys location within the Bunakha HPP's AoI (assumed 20 km travel distance in the Direct AoI) 88
Figure 17: Terrestrial biodiversity survey points (ST-#) within the Bunakha HPP's AoI.... 91
Figure 18: Schematic representation of the sample plots used in the terrestrial vegetation field surveys within the Bunakha HPP's AoI 92
Figure 19: Aquatic biodiversity and water quality survey points (A#) within the Bunakha HPP's AoI..... 98
Figure 20: Macroinvertebrates sampling using a kick net (March 2025) 99
Figure 21: Selected images of the socio-economic survey within Bunakha HPP's AoI in April 2025. Left: Bunakha Chiwog. Right: Chanachen Chiwog 107
Figure 22: Selected images of the consultations undertaken during the socio-economic survey within Bunakha HPP's AoI in April 2025. Left: Tshimalakha Chiwog. Right: Lobneykha Chiwog..... 108
Figure 23: Methodology framework for the E-flow assessment for the Bunakha HPP ... 110
Figure 24: Schematic representation of the approach used for the Critical Habitat Screening for the Bunakha HPP..... 115
Figure 25: Schematic representation of the approach used for the CHA for the Bunakha HPP 118
Figure 26: The Consultant's methodology for assessment of the significance of impacts 121
Figure 27: General layout of project components as per UDPR (Nov, 2025)..... 128
Figure 28: General layout of project components (As per revised concept)..... 130
Figure 29: Landslide and lineament map of the study area (Updated DPR, February 2026) 137

Figure 30: Seismicity zonation map showing major fault and thrust, Seismicity and seismogenic source zones provided by the Department of Earthquake Engineering, Indian Institute of Technology Roorkee (2015)..... 142
Figure 31: Streamflow at damsite and watershed looking u/s from the dam site on 21 Jan 2025..... 143
Figure 32: Topographical variation of the Wangchhu basin upstream of the Bunakha HPP 144
Figure 33: Protected areas, biological corridors, KBAs and IBAs surrounding the Bunakha HPP's AoI..... 160
Figure 34: Location of the Bunakha HPP between the districts of Paro and Chhukha... 172
Figure 35: Gewogs within Paro and Chhukha Dzongkhags and relation to the Project's AoI 173
Figure 36: Bunakha and Chanachen Chiwogs located respectively at the left and right riverbanks; the reservoir (FRL) is marked with a dark blue line 177
Figure 37: Shemagangkha and Tsamdrak Chiwogs (upstream of the Bunakha dam) ... 178
Figure 38: Key sensitive communities in the Bunakha HPP's AoI..... 179
Figure 39: Picture taken 21.01.2025 within project boundary of community structures.. 186
Figure 40: Picture taken 22.01.2025 within project boundary of community structures. 187
Figure 41: Key sensitive religious and cultural heritage sites in the Bunakha HPP's AoI 189
Figure 42: Map showing precipitation trend (mm/year) at stations (with significant trend) at seasonal and annual scale..... 212
Figure 43: Map showing maximum temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale..... 213
Figure 44: Map showing average temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale..... 213
Figure 45: Map showing minimum temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale..... 216
Figure 46: Flow trend (m^3/s/year) magnitude at Bunakha dam at seasonal and annual scale 216
Figure 47: Seasonal and annual flow timeseries at Bunakha dam..... 217
Figure 48: Map showing precipitation trend (mm/year) at stations (with significant trend) at seasonal and annual scale..... 218
Figure 49: Spatio-temporal variation of relative change in average annual precipitation (ensemble median) under SSP 245..... 222
Figure 50: Spatio-temporal variation of relative change in average annual precipitation (ensemble median) under SSP 585..... 222
Figure 51: Spatio-temporal variation of relative change in winter (DJF) precipitation (ensemble median) under SSP 245..... 223
Figure 52: Spatio-temporal variation of relative change in Pre-monsoon (MAM) precipitation (ensemble median) under SSP 245..... 223
Figure 53: Spatio-temporal variation of relative change in monsoon (JJAS) precipitation (ensemble median) under SSP 245..... 224
Figure 54: Spatio-temporal variation of relative change in post-monsoon (ON) precipitation (ensemble median) under SSP 245..... 224
Figure 55: Spatio-temporal variation of relative change in winter (DJF) precipitation (ensemble median) under SSP 585..... 225

Figure 56: Spatio-temporal variation of relative change in pre-monsoon (MAM) precipitation (ensemble median) under SSP 585 225
Figure 57: Spatio-temporal variation of relative change in monsoon (JJAS) precipitation (ensemble median) under SSP 585 226
Figure 58: Spatio-temporal variation of relative change in post-monsoon (ON) precipitation (ensemble median) under SSP 585 226
Figure 59: Spatio-temporal variation of change (°C) in average annual temperature (ensemble median) under SSP 245 228
Figure 60: Spatio-temporal variation of change (°C) in average annual temperature (ensemble median) under SSP 585 229
Figure 61: Spatio-temporal variation of change (°C) in winter (DJF) temperature (ensemble median) under SSP 245 229
Figure 62: Spatio-temporal variation of change (°C) in pre-monsoon (MAM) temperature (ensemble median) under SSP 245 230
Figure 63: Spatio-temporal variation of change (°C) in monsoon (JJAS) temperature (ensemble median) under SSP 245 230
Figure 64: Spatio-temporal variation of change (°C) in post-monsoon (ON) temperature (ensemble median) under SSP 245 231
Figure 65: Spatio-temporal variation of change (°C) in winter (DJF) temperature (ensemble median) under SSP 585 231
Figure 66: Spatio-temporal variation of change (°C) in pre-monsoon (MAM) temperature (ensemble median) under SSP 585 232
Figure 67: Spatio-temporal variation of change (°C) in monsoon (JJAS) temperature (ensemble median) under SSP 585 232
Figure 68: Spatio-temporal variation of change (°C) in post-monsoon (ON) temperature (ensemble median) under SSP 585 233
Figure 69: Spatio-temporal variation of relative change in RX1day (ensemble median) under SSP 245 235
Figure 70: Spatio-temporal variation of relative change in RX1day (ensemble median) under SSP 585 235
Figure 71: Spatio-temporal variation of relative change in RX5day (ensemble median) under SSP 245 236
Figure 72: Spatio-temporal variation of relative change in RX5day (ensemble median) under SSP 585 236
Figure 73: Comparison of hydrograph based on observed and simulated daily flow timeseries at Chhukha dam station 237
Figure 74: Comparison of hydrograph based on observed and simulated monthly flow timeseries at Chhukha dam station 238
Figure 75: Projected monthly hydrograph at Bunakha dam under CMIP6 scenarios. The blue shade represents the uncertainty in projection by thirty GCM model..... 240
Figure 76: Average sediment transport on Wangchhu at Chhukha obtained from Hydrology report 242
Figure 77: Location of three glacial lakes with high GLOF hazard level identified by (Rinzin et al., 2021). Red line denotes the potential path of flood up to Bunakha dam. 245
Figure 78: Early Warning System's Communication 415

Figure 79: Flood inundation mapping- showing the maximum flood depth and extent as the dam break outflow flood propagates downstream 416
Figure 80: Map of potentially affected communities in the case of a dam break. 418
Figure 81: Map indicating the potential area of influence due to blasting**Error! Bookmark not defined.**
Figure 80: Religious and cultural heritage sites in the Bunakha HPP's AoI 528

List of Tables

Table 1: The core ESIA Team for the Bunakha HPP..... **Error! Bookmark not defined.**
Table 2: National Policy and Strategic Framework of relevance to the Bunakha HPP 2
Table 3: National legal framework of relevance to the Bunakha HPP 4
Table 4: National institutional framework of relevance to the Bunakha HPP..... 17
Table 5: Technical guidelines of relevance to the Bunakha HPP..... 21
Table 6: International conventions of relevance to the Bunakha HPP 22
Table 7: Safeguard Policy Statement of the Asian Development Bank (SPS, 2009) and its applicability to the Bunakha HPP 29
Table 8: Gap analysis between ADB's SPS (2009) and the Bhutanese national legal framework 33
Table 9: Key Regulatory Standards and Guidelines for Air Quality applicable to the Bunakha HPP 41
Table 10: Key Regulatory Standards and Guidelines for Noise applicable to the Bunakha HPP 42
Table 11: Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the Protection of Environmental and Human Health for Residential/Parkland use..... 43
Table 12: Details of tunnel and underground works..... 58
Table 13: Total area required for residential buildings during the operational phase of the Bunakha HPP 59
Table 14: Contractor's construction facilities (CCFs) type and area required for the Bunakha HPP 67
Table 15: Water sources for the construction of the Bunakha HPP 68
Table 16: Construction power requirements of the Bunakha HPP 69
Table 17: Workforce requirements of the Project authority for the pre-Construction period of the BHPP 70
Table 18: Estimated workforce for the contractor during the peak-construction stage of the Bunakha HPP 73
Table 19: Reservoir parameters of the Bunakha HPP 73
Table 20: Nature and status of the baseline surveys undertaken for the Bunakha HPP . 81
Table 21: Physicochemical water parameters, sampling techniques, preservation methods, and holding times of the water quality survey undertaken during the three-seasons aquatic biodiversity surveys at the Bunakha HPP's AoI 101
Table 22: Criteria used for the assessment of habitat integrity (Kleynhans, Cj. 1996) .. 103

Table 23: Descriptive classes for the assessment of modifications to habitat integrity used in the application of the IHI (adapted from Kleynhans, Cj., 1996) 105
Table 24: Ecological categories, key colours, category descriptions (adapted from Kleynhans, Cj., 1996) and correlation with habitat categories as per ADB SPS/IFC PS 6 105
Table 25: Critical habitat criteria and thresholds for the Bunakha HPP..... 116
Table 26: Seasonal comparison of fish diversity and abundance recorded during the surveys for the Bunakha HPP 153
Table 27: Seasonal comparison of macroinvertebrate diversity recorded during the surveys for the Bunakha HPP..... 153
Table 28: Water quality (biodiversity-relevant parameters) recorded during the surveys for the Bunakha HPP..... 154
Table 29: Seasonal Biodiversity Patterns in the Bunakha HPP's AoI 157
Table 30: Protected areas, biological corridors, KBAs and IBAs surrounding the Bunakha HPP's AoI..... 158
Table 31: EAAAs and AOHs for terrestrial and aquatic species 169
Table 32: Species meeting Critical Habitat criteria 1-3 and thresholds..... 170
Table 33: Near-threshold, and socio-economically and culturally significant species ... 170
Table 34: Key social indicators of the Chhukha Dzongkhag..... 175
Table 35: 182
Table 36: Indigenous Peoples Screening Against ADB SPS Criteria 184
Table 37: Important environmental and social components (IESCs) for the Bunakha HPP 193
Table 38: Classification of the sensitivity level of the physical environment IESCs..... 199
Table 39: Classification of the sensitivity level of the biological environment IESCs..... 201
Table 40: Classification of the sensitivity level of the human environment IESCs..... 203
Table 41: Annual energy generation for Bunakha HPP for different exceedance probability 205
Table 42: List of stations in the Wangchhu basin used for rainfall and temperature trend analysis..... 209
Table 43: Precipitation trend analysis at all stations in the vicinity of Wangchhu basin. 210
Table 44: Average temperature trend analysis at all stations in the vicinity of Wangchhu basin 214
Table 45: The climate models of the Coupled Intercomparison Project Phase 6 (CMIP6) in CCKP..... 219
Table 46: Projected changes (%) in precipitation in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios..... 221
Table 47: Projected changes (°C) in average temperature in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios..... 227
Table 48: Projected changes (%) in extremes in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios..... 234
Table 49: Projected changes (%) in streamflow in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios..... 239

Table 50: Projected changes (%) in streamflow in mid future (MF: 2040-2059) under different climate change scenarios 240
Table 51: List of past GLOF events in the Bhutan Himalaya. Modified from (Rinzin et al., 2021) and (F. Shrestha et al., 2023) 243
Table 52: Potential lakes with high hazard GLOF risks in Wangchhu basin, upstream of Bunakha dam 244
Table 53: Climate Risk Assessment and Management Plan for the Bunakha HPP 249
Table 54: Summary of the expected positive impacts of the Bunakha HPP on the physical environment 254
Table 55: Summary of the significance of the environmental impacts of the Bunakha HPP during pre-construction 293
Table 56: Summary of the significance of the environmental impacts of the Bunakha HPP during construction 295
Table 56: Summary of the significance of the environmental impacts of the Bunakha HPP during operation 296
Table 58: Summary of the significance of the social impacts of the Bunakha HPP 333
Table 59: Environmental and Social Management Plan for the Pre-construction-Physical Environment 354
Table 60: Environmental and Social Management Plan for the Pre-construction-Biological Environment 357
Table 61: Environmental and Social Management Plan for the Pre-construction-Human Environment 359
Table 62: Environmental and Social Management Plan for the Construction-Physical Environment 362
Table 63: Environmental and Social Management Plan for the Construction-Biological Environment 367
Table 64: Environmental and Social Management Plan for the Construction-Human Environment 370
Table 65: Environmental and Social Management Plan for the Operation-Physical Environment 373
Table 66: Environmental and Social Management Plan for the Operation-Biological Environment 376
Table 67: Environmental and Social Management Plan for the Operation-Human Environment 377
Table 68: Plans related to CAT 386
Table 69: Institutional responsibilities 386
Table 70: Monitoring Indicators 386
Table 71: Indicative Cost Estimate for CAT Measures 387
Table 72: List of plants suitable for Bunakha HPP 390
Table 73: Expected Cost for Afforestation 392
Table 74: Compensatory Afforestation Plan 394
Table 75: Schedule for training and awareness raising 412
Table 76: Observations from results of the dam break modelling at different locations downstream Location downstream of Bunakha Dam 417
Table 77: Estimated Cost 423
Table 78: Species Rescue Plan Implementation and Monitoring Schedule 424
Table 79: Estimated Cost 429

Table 80: Fisheries Conservation and Management Plan Implementation and Monitoring Schedule 431
Table 81: Monitoring program 435
Table 82: Type of workers engaged and key risk and mitigation action 439
Table 83: Complaint resolution process 443
Table 84: Monitoring program 453
Table 85: Monitoring and Compliance Program 456
Table 86: Monitoring program 460
Table 87: Monitoring program 465
Table 88: Monitoring program 468
Table 89: Monitoring program 471
Table 90: Monitoring and Compliance Program 475
Table 91: Resources Required 475
Table 92: Institutional Arrangements 476
Table 93: Monitoring program 478
Table 94: Risk categories 483
Table 95: Implementation and Monitoring matrix 493
Table 96: Monitoring parameters 497
Table 97: OHS budget 498
Table 98: Potential impacts 500
Table 99: Monitoring Plan 504
Table 100: Potential Impacts 505
Table 101: Sensitive Receptors 506
Table 102: Blasting signals 508
Table 103: Environmental Management Measures 509
Table 104: Blasting Operation Monitoring Plan 510
Table 105: Potential Impacts 513
Table 106: Mitigation Measures 515
Table 107: Monitoring Summary 517
Table 108: Description of muck disposal area 520
Table 109: Volume to muck generation and disposal 521
Table 110: Potential Impacts and Mitigation Measures 521
Table 111: Monitoring Plan 524
Table 112: Responsibilities 526
Table 113: Cultural and religious sites and Neys in the two Gewogs 528
Table 114: Major Issues raised during public consultation and physical survey assessment 530
Table 115: Potential Impacts 531
Table 116: Site specific mitigation measures 532
Table 117: Enhancement measures 533
Table 118: BHPL Responsibility 533
Table 119: Contractor Responsibility 534
Table 120: Cultural Heritage Management Plan - Monitoring Program 535
Table 121: Suggestion of an internal inspection plan for the Bunakha HPP 540
Table 122: Suggestion of an external auditing plan for the BHPP 541
Table 123: Environmental and Social Monitoring Programme for the Bunakha HPP - compliance monitoring 542

Table 124: Environmental and Social Monitoring Programme for the Pre-construction of the Bunakha HPP - effects monitoring..... 557
Table 125: Environmental and Social Monitoring Programme for the Construction of the Bunakha HPP - effects monitoring..... 561
Table 126: Environmental and Social Monitoring Programme for the Operation of the Bunakha HPP - effects monitoring..... 567
Table 127: Environmental and Social Monitoring Programme for the Decomissioning of the Bunakha HPP - effects monitoring..... 570
Table 128: Environmental Valuation of BHPP Area (Based on Kubiszewski et al., 2013) 573
Table 129: Benefits from BHP..... 574
Table 130: Comparative Assessment..... 575
Table 131: Trade-off and Mitigation Balance..... 576
Table 132:: Net Benefit Summary 576
Table 133: Fish Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status 2
Table 134: Dominant Tree Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status 4
Table 135: Mammal Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status..... 6
Table 136: Bird Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status 7
Table 137: Herpetofauna Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status (top of form) 11
Table 138: Invasive Plant Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status (top of form) 12

List of Abbreviations and Acronyms

ADB	Asian Development Bank
AoI	Area of Influence
BPL	Below Poverty Line
BHPL	Bunakha Hydropower Project Limited
CCF	Contractor's Construction Facility
CHS	Community Health and Safety
CoI	Corridor of Impact
CVC-BP	Conventional Concrete Batching Plant
DAO	Dzongkhag Agriculture Officer
DE	Dzongkhag Engineer
DGPC	Druk Green Power Corporation
DPs	Displaced Persons
EA	Executive Agency
EIA	Environmental Impact Assessment
EM	Entitlement Matrix
E&S	Environmental and Social
ESF	Environment and Social Framework
ESMU	Environment and Social Management Unit
ESHS	Environmental, Social, Health and Safety
ESIA	Environmental and Social Impact Assessment
ESSs	Environment and Social Standards
EPC	Engineering, Procurement and Construction
ESMP	Environmental and Social Management Plan
FGDs	Focus Group Discussions
GAO	Gewog Administration Officer
GRC	Grievance Redress Committee
GRM	Grievance Redress Mechanism
HHs	Households
HP	Hydropower
HPP	Hydropower Plant
HSE	Health Safety and Environment
IAPs	Interested and affected parties
IBA	Important Bird Area
IFC PS	International Finance Corporation Performance Standards on Environmental and Social Sustainability
IPCC	Intergovernmental Panel on Climate Change
IR	Involuntary Resettlement
IUCN	International Union for Conservation of Nature
KII	Key Informants Interview
kV	Kilovolt
LACRR	Land Acquisition and Compensation Rules and Regulations
LRO	Land Record Officer
MSDS	Material Safety Data Sheet
MW	Megawatt
MWh	Megawatt hour
MWp	Megawatt peak
NEC	National Environment Commission
OHL	Overhead Line
OHS	Occupational Health and Safety
O&M	Operation and Maintenance
PAH	Project Affected Households
PAP	Project Affected Person
PAVA	Property Assessment and Valuation Agency

PIU	Project Implementation Unit
PSC	Project Supervision Consultant
PPE	Personal Protection Equipment
RGoB	Royal Government of Bhutan
RP	Resettlement Plan
SESAH	Socio-economic Survey of Affected Households
SPS	Safeguard Policy Statement
VAH	Vulnerable Affected Household
TOR	Terms of Reference

Glossary of Terms

Administrative/ implementation service costs	Administrative costs cover costs for (i) staff; (ii) consultants; (iii) resettlement plan implementing non-government organizations; (iv) office space; (v) equipment; (vi) preparation of a resettlement plan, including conducting the census and various studies; (vii) transport; and (viii) training and capacity building
Associated facilities (according to ADB SPS, 2009)	Associated facilities that are not funded as part of the project (funding may be provided separately by the borrower/client or by third parties), and whose viability and existence depend exclusively on the project and whose goods or services are essential for successful operation of the project.
Chiwog	Group of villages under the Gewog
Compensation	The payment in cash or kind for private property acquired by government for the project, based on replacement value
Consultation	The process of deliberation, discussion and dialogue between developers and IAPs
Contingency	Contingency is meant to cover costs that are invisible while preparing a resettlement plan or E&S management plans, but that may arise during implementation. Resettlement site development, income restoration, E&S monitoring and other similar activities may entail unforeseen costs. Contingency is usually assigned as a percentage of total estimated implementation costs
Costs for monitoring and evaluation	Monitoring and evaluation costs include costs on periodic (a) monitoring of the resettlement/E&S management plan implementation by the executing agency, (b) verification of monitoring by external experts of the resettlement/E&S management plan implementation of category A projects, and (c) evaluation of the resettlement/E&S management plan implementation.
Cut-off Date	The date established by the Developer and disclosed to affected persons, after which people moving into the project area or assets acquired will not be eligible for compensation or assistance.
Direct Project-Affected People (Direct PAP), Direct Project-Affected Households (Direct PAHs)	Any person, persons or households who, because of Project activities, would have their: (i) standard of living adversely affected; (ii) legally recognized title or not, or interest in any house, land (including residential, agricultural and grazing land) or any other moveable or fixed assets acquired or possessed, in full or in part, permanently or temporarily, and; iii) place of work or residence or habitat adversely affected, with or without displacement.
Disclosure	The formal-sounding term for making information accessible to IAPs
Dzongkhag	Administrative District

Entitled Person	Any individual, household, or entity that has a recognized right or claim to compensation, assistance, or other benefits under a project's resettlement and livelihood restoration plan. This includes: ▪ Persons with formal legal rights to land or assets (e.g., owners with titles). ▪ Persons without formal legal rights but with recognizable claims under national law or customary practices. ▪ Occupants or users present before the cut-off date, even if they lack legal documentation. ▪ Vulnerable groups who may require special assistance to restore livelihoods.
Gerab Dratshang	Central Monastic Body of Bhutan
Gewog	Block under the Dzongkhag
Gup	Elected head of Block
Interested and affected parties (IAPs)	The group composed of project-affected people and interested parties
Interested parties	Those who might have an interest in, or may influence, the Project
Lag- thram	The official land ownership certificate issued by the National Land Commission. It serves as the primary legal document proving who owns a particular plot of land and is required for buying, selling, transferring, or mortgaging land in Bhutan. [1]
Mangmi	Elected Member of the local Government
Micro-invertebrates	Very small invertebrate animals, typically less than 1 mm in size, and often microscopic. They include organisms such as rotifers, tiny crustaceans (e.g., cladocerans/water fleas, copepods, ostracods), mites, springtails, nematodes, and tardigrades.
Periphyton	The community of algae, cyanobacteria, microbes, and trapped organic matter that grows attached to submerged surfaces in aquatic environments. It forms a thin to thick, often slimy layer on rocks, plants, wood, or artificial structures underwater.
Phytoplankton	Free-floating, microscopic, photosynthetic organisms—including algae, protists, and cyanobacteria—that inhabit the illuminated upper layers of aquatic environments and serve as primary producers in marine and freshwater ecosystems.
Project Affected Households	All members of a project-affected household residing under one roof and operating as a single economic unit, who are adversely affected by the project or any of its components. For rehabilitation purposes, affected persons will be considered as members of affected households.
Project-Affected People , Project-Affected Persons , Project-Affected Communities and Project-Affected Parties	Every governmental or administrative body, every community, non-governmental organization, groups or individual persons who might get affected (directly or indirectly, positively or negatively, and those severely affected) by the Project.

[1] Based on: https://web.nlcs.gov.bt/wp-content/uploads/2024/03/circular-2.pdf

Rehabilitation	The measures taken to mitigate social impacts, including compensation, resettlement and rehabilitation allowances where required
Replacement Cost	The open/fair market value of a project affected property. For agriculture land, this includes reference to land of equal size, type and productive potential in the vicinity of the affected land and land preparation cost where required. For houses and other buildings, this includes reference to the market price of materials and labor, and the cost of transporting materials to the building site. The replacement cost further includes the cost of any registration and transfer taxes for land and buildings. ADB SPS, 2009: The calculation of full replacement cost will be based on the following elements: (i) fair market value; (ii) transaction costs; (iii) interest accrued, (iv) transitional and restoration costs; and (v) other applicable payments,
Relocation cost	These cover costs incurred in the physical relocation of people, businesses and other moveable properties. These also include the cost of acquiring land for resettlement, developing the site, and replacing all lost private and community assets, including electricity, roads and bridges. Costs for site preparation for farmers include the costs of providing irrigation infrastructure and access to agriculture services, including access to credit, extension, and marketing facilities
Stakeholder	Same as IAPs
Shared Socioeconomic Pathways (SSPs)	Shared Socioeconomic Pathways (SSPs) are climate change scenarios of projected socioeconomic global changes up to 2100 as defined in the IPCC Sixth Assessment Report on climate change in 2021. They are used to derive greenhouse gas emissions scenarios with different climate policies. The five scenarios are: ▪ SSP1: Sustainability ("Taking the Green Road") ▪ SSP2: "Middle of the Road" ▪ SSP3: Regional Rivalry ("A Rocky Road") ▪ SSP4: Inequality ("A Road Divided") ▪ SSP5: Fossil-fueled Development ("Taking the Highway")
Titleholder	The person in whose name the project-affected business, land and/ or building is registered and who is authorized to receive the compensation granted for the loss of business or acquisition of the land
Tshogpas	Elected member of the Chiwog
Vulnerable groups (according to ADB's SPS, 2009)	Those groups below the poverty line, the landless, the elderly, women and children, Indigenous Peoples, and those without legal title to land.
Zooplankton	Heterotrophic (organisms that cannot produce their own organic food from inorganic substances and therefore must obtain organic carbon by consuming other organisms or their by-products), free-floating aquatic organisms that drift with currents and form the animal component of the plankton community.

Executive Summary

This document is a Draft ESIA Report for the Bunakha Hydropower Project (BHPP) in Bhutan. It presents the Project description, the applicable policy/legal/institutional framework, the ESIA methodology, baseline environmental and social conditions, and the assessment of potential risks and impacts across Project phases. It also outlines proposed mitigation and monitoring measures and the management framework to be implemented through the ESMP, supported by stakeholder engagement and grievance redress arrangements.

1. Project Overview

The Bunakha Hydropower Project (BHPP) is a proposed 180 MW storage hydropower project located on the Wangchhu River in Chhukha Dzongkhag, western Bhutan. The Project is being developed by Bunakha Hydropower Project Limited (BHPL), a Special Purpose Vehicle (SPV) established by Druk Green Power Corporation Limited (DGPC). As the uppermost storage project within the Wangchhu hydropower cascade, BHPP will regulate seasonal river flows, improve dry-season power generation, and enhance the operational performance of downstream hydropower facilities, including the existing Chhukha (336 MW) and Tala (1,020 MW) hydropower plants, as well as the proposed Wangchhu Hydropower Project (570 MW, under development). Refer to Table A for Key project Information below.

Table 1: Key Project Information

Item	Description
Project Name	Bunakha Hydropower Project (BHPP)
Project Proponent	Bunakha Hydropower Project Limited (BHPL)
Parent Organization	Druk Green Power Corporation Limited (DGPC)
Project Location	Wangchhu River, Chhukha Dzongkhag, Bhutan
Project Type	Storage Hydropower Project
Installed Capacity	180 MW
Dam Type	Roller Compacted Concrete (RCC) Dam
Dam Height	205 m
ADB Safeguard Category	Category A (Environment)
ESIA Standard	ADB Safeguard Policy Statement (2009)
Directly Affected Households	44 households (218 persons)- inlcuded non titled resource user
Physically Displaced Households	1 household (included in Severely Affected Households)
Severely Affected Households	35 households
Vulnerable Households	9 households
Indigenous Peoples Safeguard	Not Triggered

Estimated GHG Emission Reduction	Approximately 572,352 tCO_2e/year
Key Safeguard Instruments	ESMP, RP, BAP, SEP, LMP, Environmental Flow Management Plan with other sub-management plans, Climate Risk Management Plan, ESMoP

The Project comprises a 205 m high Roller Compacted Concrete (RCC) dam, a reservoir covering approximately 440 ha at Full Reservoir Level (FRL 2,006 masl), an underground powerhouse equipped with three 60 MW Francis turbine-generator units, transmission infrastructure, access roads, contractor facilities, and associated permanent and temporary works. The Project is expected to generate approximately 830 GWh of renewable electricity annually, while regulated releases from the reservoir are projected to contribute an additional 632 GWh per year through improved downstream cascade generation.

The Project will strengthen Bhutan's long-term energy security, support renewable electricity exports, improve seasonal water regulation, and contribute to regional decarbonization. It is estimated to avoid approximately 572,352 tons of carbon dioxide equivalent (tCO_2e) annually by displacing fossil fuel-based electricity generation, thereby supporting Bhutan's commitment to maintaining carbon neutrality.

The Royal Government of Bhutan has sought financial assistance from the Asian Development Bank (ADB) under the Green Power Project Readiness Enhancement initiative to update the Detailed Project Report (DPR) and prepare the Environmental and Social Impact Assessment (ESIA). In accordance with the ADB Safeguard Policy Statement (SPS, 2009), the Project has been classified as Category A for Environment, requiring a comprehensive assessment of environmental and social impacts and the preparation of appropriate safeguard instruments.

2. Policy, Legal and Safeguard Framework

The BHPP has been planned and assessed in accordance with the applicable environmental and social legislation, policies, regulations, and standards of the Royal Government of Bhutan, relevant international environmental agreements, and the requirements of the Asian Development Bank (ADB) Safeguard Policy Statement (SPS, 2009). The ESIA also reflects international good practice for large hydropower developments, particularly in relation to biodiversity conservation, occupational and community health and safety, climate resilience, stakeholder engagement, and environmental and social risk management.

A comprehensive review of the national legal and institutional framework, together with a gap analysis between Bhutanese legislation and the ADB SPS (2009), was undertaken to identify additional safeguard requirements. Where differences were identified, project-specific measures have been incorporated to ensure compliance with both national legislation and ADB safeguard requirements.

To implement these commitments, an integrated suite of safeguard instruments has been prepared, including the Environmental and Social Management Plan (ESMP), Resettlement Plan (RP), Biodiversity Action Plan (BAP), Stakeholder Engagement Plan (SEP), Labor Management Plan (LMP), Environmental Flow Management Plan, Climate Risk Management Plan, Cultural Heritage Management Plan, Community Health and Safety Plan, Dam Safety Emergency Preparedness Plan, Grievance Redress Mechanism (GRM), and the Environmental and Social Monitoring Programme (ESMoP).

Collectively, these safeguard instruments establish the institutional arrangements, mitigation measures, monitoring requirements, and reporting mechanisms necessary to effectively manage environmental and social risks throughout Project implementation and ensure compliance with national regulatory requirements and the ADB SPS (2009).

3. Environmental and Social Impact Assessment Approach

The ESIA is based on comprehensive three-season baseline investigations undertaken during 2024 - 2025, covering the physical, biological, aquatic, and socio-economic environments within the Project Area of Influence. Primary field investigations were complemented by secondary data review, engineering studies, spatial analysis, and stakeholder consultations to establish baseline conditions, assess potential impacts, and develop appropriate mitigation and management measures.

Specialist studies included environmental flows, terrestrial and aquatic biodiversity, Critical Habitat, cumulative impacts, climate change and disaster risk, air and water quality, noise, socio-economic conditions, land acquisition and resettlement, occupational and community health and safety, labor and working conditions, cultural heritage, and gender and social inclusion. Together, these studies provide a comprehensive understanding of the Project's environmental and social setting and form the basis for the impact assessment.

Meaningful stakeholder engagement was undertaken throughout the ESIA process with government agencies, local authorities, affected communities, women, vulnerable groups, and other interested stakeholders. Feedback from these consultations informed Project design, impact mitigation, and safeguard planning. A Grievance Redress Mechanism (GRM) has also been established to provide an accessible and transparent process for addressing concerns during Project implementation.

Potential impacts were evaluated considering the sensitivity of environmental and social receptors together with the magnitude, extent, duration, reversibility, and likelihood of Project-related changes. The assessment provides the basis for the Environmental and Social Management Plan (ESMP) and the associated safeguard instruments that guide implementation, monitoring, and continual improvement throughout Project implementation.

4. Baseline Environmental and Social Conditions

Comprehensive baseline investigations undertaken during 2024 - 2025 established the existing environmental and social conditions within the Project Area of Influence (AoI) and provide the reference against which Project-related impacts will be assessed and monitored. The studies confirmed that the Project is located within a relatively undisturbed Himalayan landscape of high ecological value, while also supporting rural communities that depend primarily on agriculture and natural resources.

Physical Environment

The Project is located within the Wangchhu River Basin in western Bhutan, a mountainous landscape characterized by steep valleys, rugged terrain, temperate forests, and relatively intact natural ecosystems. Baseline investigations confirmed that surface water quality is generally good, with most physico-chemical parameters complying with applicable standards and heavy metals below detectable limits. Localized bacteriological contamination was identified at some

locations, indicating the need for appropriate treatment before direct human consumption. Ambient air quality and noise levels were generally consistent with rural conditions, with only localized exceedances attributable to natural conditions and existing local activities.

The Project area lies within the geologically active Himalayan region and is susceptible to natural hazards, including earthquakes, landslides, Glacial Lake Outburst Floods (GLOFs), Landslide Dam Outburst Floods (LDOFs), intense rainfall, and slope instability. These risks have been incorporated into Project planning through appropriate engineering design, dam safety provisions, slope stabilization measures, and emergency preparedness planning.

Biological Environment

The Project Area of Influence supports diverse terrestrial and aquatic ecosystems representative of Bhutan's temperate Himalayan landscape. Three-season biodiversity surveys recorded 97 bird species, 10 mammal species, 28 herpetofauna species, and 45 tree species, together with diverse fish and aquatic macroinvertebrate communities, indicating generally healthy ecosystem conditions. Several nationally and globally threatened species occur within the wider landscape.

Although the Project does not directly overlap any protected area, the surrounding landscape includes Jigme Dorji National Park, Jigme Khesar Strict Nature Reserve, Biological Corridors, Key Biodiversity Areas (KBAs), and Important Bird Areas (IBAs). These ecological values have been incorporated into Project planning through avoidance of sensitive habitats where practicable, minimization of disturbance, habitat restoration, and implementation of the Biodiversity Action Plan.

Critical Habitat Assessment

The Critical Habitat Assessment undertaken in accordance with the ADB SPS (2009) identified biodiversity features meeting Critical Habitat criteria within the broader landscape. More than 2,000 terrestrial and aquatic species were screened, with six species confirmed to trigger Critical Habitat criteria, while the Kamji and Paro Wetland KBAs also qualify as Critical Habitat under Criterion 6.

Although no Critical Habitat occurs within the permanent Project footprint that would preclude Project development, the wider landscape contains biodiversity values of international importance. Accordingly, the Project incorporates biodiversity avoidance and mitigation measures, habitat restoration, long-term monitoring, and implementation of the Biodiversity Action Plan, to support the objective of No Net Loss of biodiversity in natural habitats and conservation of Critical Habitat values.

Climate Change and Disaster Risk

The Climate and Disaster Risk Assessment evaluated the potential effects of changing temperature and precipitation patterns, extreme rainfall events, GLOFs, LDOFs, sedimentation, and slope instability on Project infrastructure and downstream communities. The assessment indicates that these risks can be effectively managed through climate-resilient engineering design, reservoir operation, sediment management, dam safety measures, and emergency preparedness.

Social Environment

Household census surveys, asset inventories, and stakeholder consultations identified 44 affected households (30 HH titleholders +14 collector households) comprising 218 persons within the Project Area of Influence. Agriculture is the primary livelihood, supplemented by livestock rearing, wage employment, small businesses, and government service. Women own approximately 70% of affected landholdings, reflecting local matrilineal traditions, and gender-responsive measures have been integrated into Project planning.

Of the affected households, 35 are classified as Severely Affected Households, while one household will require physical relocation. Nine households are considered vulnerable and will receive targeted assistance through the Resettlement Plan and Livelihood Restoration Programme. Screening undertaken in accordance with the ADB SPS (2009) confirmed that the Indigenous Peoples safeguard is not triggered.

Overall, the baseline studies demonstrate that the Project Area possesses high environmental and social sensitivity while providing a sound basis for impact assessment, mitigation planning, and long-term environmental and social monitoring.

5. Key Environmental and Social Impacts

The ESIA identified and assessed the potential environmental and social impacts of the BHPP during the pre-construction, construction, operation, and decommissioning phases. The assessment considered the sensitivity of environmental and social receptors together with the magnitude, extent, duration, reversibility, and likelihood of Project-related impacts. Mitigation measures have been developed in accordance with the mitigation hierarchy to avoid, minimize, restore, and, where necessary, compensate for adverse impacts.

Environmental Impacts

The principal environmental impacts are associated with permanent reservoir inundation, vegetation clearance, habitat loss and alteration, changes to downstream flow regimes and sediment transport, and temporary construction-related impacts such as dust, noise, wastewater generation, spoil disposal, traffic, and soil erosion. Construction activities may also result in temporary disturbance to terrestrial and aquatic habitats if not properly managed.

During operation, the Project will modify downstream hydrology and aquatic habitat conditions. These impacts will be managed through implementation of environmental flow releases, sediment management, pollution prevention measures, progressive site rehabilitation, and associated safeguard plans, including the Biodiversity Action Plan, Fisheries Conservation and Management Plan, Catchment Area Treatment Plan, Species Rescue Plan, and Compensatory Afforestation Programme. Through these measures, the Project seeks to minimize biodiversity impacts while supporting the objective of No Net Loss of biodiversity in natural habitats.

Social Impacts

The principal social impacts relate to permanent land acquisition, loss of agricultural land and livelihoods, physical relocation of one household, temporary disruption to local access and community infrastructure, labour influx, increased traffic, and occupational and community health and safety risks during construction.

A total of 44 households (30 HH titleholders and 14 collector householders) comprising of 218 household members will be directly affected, including 35 Severely Affected Households and one physically displaced household. Affected households will receive compensation at replacement cost together with livelihood restoration assistance in accordance with the Resettlement Plan (RP) and Livelihood Restoration Programme. Additional support measures have been incorporated for vulnerable households to ensure that Project impacts do not disproportionately affect disadvantaged groups.

Potential impacts on cultural and religious resources have been minimized through Project design and will be managed through site-specific protection measures, stakeholder consultation, implementation of the Cultural Heritage Management Plan, and chance-find procedures. Community health and safety risks associated with construction activities will be managed through appropriate traffic management, emergency preparedness, worker management, and continuous stakeholder engagement.

Residual Impacts and Project Benefits

Following implementation of the proposed mitigation measures and safeguard plans, most environmental and social impacts are expected to be reduced to Low or Moderate significance. Residual impacts of High significance remain primarily associated with permanent reservoir inundation, land acquisition, and irreversible changes to natural habitats. These impacts will be addressed through compensation at replacement cost, livelihood restoration, biodiversity conservation measures, compensatory afforestation, environmental flow implementation, and long-term environmental monitoring.

Despite these residual impacts, the Project is expected to deliver substantial long-term benefits through renewable energy generation, improved regulation of the Wangchhu hydropower cascade, strengthened national energy security, employment creation, local economic development, improved infrastructure, and reduced greenhouse gas emissions. With effective implementation of the proposed safeguard measures, the ESIA concludes that the Project's environmental and social impacts can be managed in accordance with the requirements of the Royal Government of Bhutan and the ADB Safeguard Policy Statement (SPS, 2009).

6. Cumulative Impact Assessment

A basin-wide Cumulative Impact Assessment (CIA) was undertaken to evaluate the combined environmental and social effects of the Bunakha Hydropower Project together with existing, under-construction, and planned hydropower developments within the Wangchhu River Basin. The assessment considered cumulative changes to river hydrology, sediment transport, aquatic ecology, biodiversity, ecosystem connectivity, water quality, and downstream water resource management.

As the uppermost storage project in the Wangchhu hydropower cascade, BHPP will play an important role in regulating seasonal river flows and improving the operational efficiency of downstream hydropower projects, including the existing Chhukha (336 MW) and Tala (1,020 MW) hydropower plants, as well as the proposed Wangchhu Hydropower Project. Although the Project will modify natural flow and sediment regimes, coordinated cascade operation is expected to improve dry-season water availability, optimize hydropower generation, and enhance basin-wide water resource management.

The CIA identified the principal cumulative impacts as changes in environmental flows, aquatic habitat connectivity, fish habitats, sediment dynamics, and biodiversity values within the Wangchhu River system. It also recognized the influence of climate change and natural hazards on the long-term resilience of the basin and the need for coordinated management among hydropower developments.

To address these cumulative impacts, the Project incorporates coordinated reservoir operation, environmental flow releases, integrated sediment management, biodiversity conservation, catchment restoration, climate-resilient infrastructure design, dam safety measures, emergency preparedness, and long-term environmental monitoring. Monitoring results will be periodically reviewed to refine mitigation measures and improve coordination among hydropower operators.

Overall, the CIA concludes that, with implementation of the proposed mitigation and management measures, the cumulative environmental and social impacts of the Bunakha Hydropower Project are expected to remain within acceptable levels. The Project is also expected to make a positive contribution to the sustainable development of the Wangchhu hydropower cascade by strengthening renewable energy generation, improving seasonal flow regulation, and supporting Bhutan's long-term energy security while maintaining downstream environmental and social values.

7. Environmental and Social Management Plan

A comprehensive Environmental and Social Management Plan (ESMP) has been prepared to ensure that the mitigation measures and safeguard commitments identified in the ESIA are effectively implemented throughout all phases of the Project. The ESMP establishes the institutional arrangements, mitigation measures, monitoring requirements, implementation schedules, reporting procedures, and performance indicators necessary to manage environmental and social risks and ensure compliance with the requirements of the Royal Government of Bhutan and the ADB Safeguard Policy Statement (SPS, 2009).

The ESMP is supported by the suite of safeguard instruments described in this ESIA, including the Resettlement Plan (RP), Biodiversity Action Plan (BAP), Labour Management Plan, Environmental Flow Management Plan, Environmental, Social, Health and Safety Management Plan, and other supporting management plans that together provide an integrated framework for managing environmental and social risks throughout Project implementation.

Implementation of the ESMP will be the responsibility of BHPL supported by contractors, supervision consultants, and qualified environmental, social, health, and safety (ESHS) personnel. Contractors will prepare and implement site-specific Construction Environmental and Social Management Plans (CESMPs) consistent with the ESMP, while BHPL will oversee implementation through regular inspections, compliance verification, performance reporting, and corrective action where required.

The Environmental and Social Management Framework provides an integrated mechanism for managing Project risks, coordinating implementation among all responsible parties, and ensuring effective implementation of the Project's environmental and social commitments.

8. Environmental and Social Monitoring Programme

Environmental and social Programme will be monitored throughout Project implementation to verify compliance with safeguard commitments, evaluate the effectiveness of mitigation measures, and identify any unforeseen impacts requiring corrective action. The Environmental and Social Monitoring Programme (ESMoP) provides the framework for systematic monitoring, reporting, compliance verification, and performance evaluation in accordance with the requirements of the Royal Government of Bhutan and the Asian Development Bank (ADB) Safeguard Policy Statement (SPS, 2009).

The monitoring programme includes compliance, and effects monitoring during the pre-construction, construction, operation, and decommissioning phases. Key parameters include water quality, environmental flows, air quality, noise and vibration, erosion and sediment control, waste management, terrestrial and aquatic biodiversity, habitat restoration, occupational and community health and safety, labour and working conditions, land acquisition and livelihood restoration, cultural heritage, stakeholder engagement, grievance management, and implementation of biodiversity conservation measures.

Monitoring will be undertaken by BHPL, contractors, and supervision consultants with oversight from the relevant government agencies. Contractors will carry out routine monitoring in accordance with their Construction Environmental and Social Management Plans (CESMPs), while BHPL will review compliance, verify monitoring results, and ensure that any non-compliance or unforeseen impacts are promptly addressed through appropriate corrective actions.

Monitoring findings will be documented through regular inspections, compliance reports, environmental and social monitoring reports, incident reporting, and periodic audits. The results will be used to evaluate safeguard performance, support adaptive management, and improve environmental and social performance.

Overall, the Environmental and Social Monitoring Programme provides a robust mechanism for ensuring transparency, accountability, and continual compliance with Project commitments, while supporting informed decision-making and the effective implementation of environmental and social safeguards.

9. Conclusions

The ESIA concludes that the BHPP is environmentally and socially feasible, provided that the mitigation measures and safeguard commitments identified in the ESIA and associated management plans are fully implemented. The assessment has been undertaken in accordance with the environmental legislation of the Royal Government of Bhutan, the Asian Development Bank (ADB) Safeguard Policy Statement (SPS, 2009), and internationally recognized good practice.

The Project will generate approximately 830 GWh of renewable electricity annually, improve regulation of the Wangchhu hydropower cascade, strengthen Bhutan's energy security, support regional decarbonization, and contribute to climate change mitigation by avoiding an estimated 572,352 tons of carbon dioxide equivalent (tCO_2e) annually. In addition, the Project is expected to create employment opportunities, stimulate local economic development, and improve supporting infrastructure.

The ESIA identified significant environmental and social impacts (see Table B for the key environmental and social findings) typical of large storage hydropower developments, particularly those associated with permanent reservoir inundation, land acquisition, changes in river hydrology, biodiversity, and construction-related occupational and community health and safety risks. Through implementation of the Environmental and Social Management Plan (ESMP) and associated safeguard instruments, most impacts are expected to be reduced to Low or Moderate significance. Residual impacts of High significance remain primarily associated with permanent land acquisition, reservoir inundation, and irreversible changes to natural habitats and will be managed through compensation, livelihood restoration, biodiversity conservation measures, environmental flow implementation, compensatory afforestation, and long-term monitoring.

Overall, the ESIA demonstrates that the BHPP has been designed to balance renewable energy development with environmental protection and social responsibility. With effective implementation of the proposed safeguard measures, continued stakeholder engagement, and systematic environmental and social monitoring, the Project is expected to comply with the requirements of the Royal Government of Bhutan and the ADB SPS (2009), thereby providing a sound basis for sustainable Project implementation.

Table 2: Key Environmental and Social Findings

Aspect	Summary
Environmental Quality	Generally good baseline air and water quality with localized natural constraints.
Biodiversity	High biodiversity value; no Critical Habitat within the permanent Project footprint.
Critical Habitat	Six species and two KBAs (Kamji, Paro Wetlands) meet Critical Habitat criteria in the wider landscape; no Critical Habitat within permanent Project footprint.
Climate Risk	Risks addressed through climate-resilient engineering and dam safety measures.
Social Impacts	30 households affected, including one physically displaced household.
Residual Impacts	Primarily reservoir inundation and permanent land acquisition.
Overall Conclusion	Environmentally and socially feasible with implementation of the ESMP and associated safeguard measures.

1 Introduction

1.1 The Project's Background

The proposed Bunakha Hydropower Project (BHPP) is a 180 MW dam to be located near the villages of Bunakha and Geling (the "Project"), Chhukha Dzongkhag, on the river Wangchhu, Bhutan. The Project is planned as the most upstream component in a cascade of at least four projects along the Wangchhu River. These include the existing 336 MW Chhukha HPP, situated 3.25 km downstream from the proposed Bunakha dam site; the existing 1,020 MW Tala HPP, located 15 km downstream; and the proposed 570 MW Wangchhu HPP, at a distance downstream yet to be confirmed.

All four plants would operate together, with Bunakha HPP serving as a large water storage reservoir. It will provide peak power generation and ensure dependable dry-season water flow, boosting the downstream plants' total annual electricity production by an estimated 632 Gigawatt-hours (GWh).

The Project site is accessible via the Phuntsholing-Thimphu highway. Construction will involve a 205-meter-high dam, a 860.73 acres reservoir, and a powerhouse located at the riverbed adjacent to the dam.

DGPC will establish a Special Purpose Vehicle (SPV) for the Bunakha Hydropower Project, named Bunakha Hydro Power Limited (BHPL). BHPL will serve as the designated Project developer and implementing entity responsible for all aspects of Project development, construction, and operation. As the Project owner, BHPL will hold overall responsibility for ESHS performance and compliance, including implementation of the ESMP, Resettlement Plan, and all associated safeguard commitments in accordance with ADB SPS (2009) and applicable national regulations.

2 Policy, Legal and Institutional Framework

To ensure full regulatory alignment, the Project's design, construction, and commissioning will be conducted in accordance with Bhutan's national policies and legal framework and the Asian Development Bank's Safeguard Policy Statement (2009). This section provides an overview of the governing framework, detailing the key national laws, policies, and guidelines. It also covers the applicable international environmental and social (E&S) standards, including conventions to which Bhutan is a party and describes the institutional structure for the Environmental and Social Impact Assessment (ESIA) process. A detailed summary of this legal and policy framework is provided in Annex 2: National Policy and Strategic Framework for further reference.

2.1 National Policy and Strategic Framework

The Project- and ESIA-relevant national policies and strategies, as well as their applicability to the Project are summarized in Table 3 and detailed in Annex 2.1.

Table 3: National Policy and Strategic Framework of relevance to the Bunakha HPP

Policy	Summary description	Applicability to the Project
National Energy Policy 2025	It consolidates and supersedes several prior frameworks, including the Bhutan Sustainable Hydropower Development Policy 2021, Alternative Renewable Energy Policy 2013, Domestic Electricity Tariff Policy 2016, and National Energy Efficiency & Conservation Policy 2019. It marks a strategic shift by opening hydropower and solar development to private and foreign investment under defined conditions, with an estimated USD 26 billion needed by 2040. Hydropower projects are classified as Mega (>1000 MW), Large (501–1000 MW), Medium (101–500 MW) and Small (≤100 MW).	Applicable. The policy explicitly prioritizes storage/reservoir because they address the seasonal generation gap
National Gender Equality Policy (NGEP), 2020	Bhutan's NGEP, 2020 provides a framework for achieving substantive equality, ensuring all individuals have equitable opportunities to participate in the country's development, regardless of gender. The policy aims to eliminate discrimination and abuse, promote gender parity in public administration and other sectors, and requires the collection of sex-disaggregated data for evidence-based interventions.	Applicable. In the ESIA context, socio-economic data collection is sex-disaggregated; a Gender Action Plan (GAP) is being prepared; the ESMP will contain gender-tailored measures were deemed relevant.
National Policy for Persons with Disabilities, 2019	The National Policy for Persons with Disabilities promotes the rights, inclusion, accessibility, and participation of people with disabilities in all aspects of social and economic development. The policy seeks to eliminate discrimination and ensure equal access to services, infrastructure, employment, and public participation.	Applicable. The Bunakha HPP may affect vulnerable populations, including people with disabilities. The ESIA, Stakeholder Engagement Plan (SEP), Gender and Vulnerability Action Plan (GVAP), and Grievance Redress Mechanism (GRM) incorporate

Policy	Summary description	Applicability to the Project
		measures to ensure meaningful participation, equitable access to information, and consideration of the specific needs of persons with disabilities throughout the project lifecycle.
National Policy for Senior Citizens, 2023	The National Policy for Senior Citizens promotes the wellbeing, dignity, care, and social inclusion of elderly persons and recognizes their rights to participate in development processes and access public services.	Applicable. Elderly persons have been identified as a potentially vulnerable group within the Project Area of Influence. The ESIA and associated management plans include measures to ensure that elderly persons are consulted during project planning and implementation and that their specific vulnerabilities are considered in impact mitigation and emergency preparedness planning.
Climate Change Policy, 2020	The Climate Change Policy emphasizes aligning climate actions with other policies and international commitments, including gender equality in climate and disaster risk strategies, and integrating cross-cutting issues like biodiversity conservation and pollution reduction. The policy commits to fulfilling obligations under the UNFCCC (United Nations Framework Convention on Climate Change) and Paris Agreement, including carbon neutrality through cooperative and non-market mechanisms.	Applicable. The Bunakha HPP supports the achievement of the climate goals. The ESIA includes preparation of a Climate Impact Assessment.
National Environment Strategy (NES) 2020-2030	The NES 2020-2030 aims at aligning all of the relevant environmental policy, legislation and regulations existing in Bhutan, as well as global commitments in terms of Multilateral Environmental Agreements. It guides implementation of the relevant policy and legislation in an integrated and strategic fashion, through a set of Strategic Objectives.	Applicable. Some Strategic objectives are directly applicable to the Bunakha HPP: energy-efficient design and resilience to earthquakes, windstorms, and other hazards; further sustainable development of hydropower; expand current hydropower capacity; protect and manage upstream watersheds; promote alternative renewable energy; carry out cumulative impact assessments; and ensure environmental flows in rivers.

2.2 National Legal Framework

The Project- and ESIA-relevant national legal documents, as well as their applicability to the Project are summarized in Table 4 and detailed in Annex 2.2.

Table 4: National legal framework of relevance to the Bunakha HPP

Legal Document	Summary Description	Applicability to the Project
A. CONSTITUTIONAL FRAMEWORK		
Constitution of the Kingdom of Bhutan, 2008	▪ Mandates the State to preserve cultural heritage and protect the environment ▪ Ensures sustainable use of natural resources, including rivers, lakes, forests, and minerals ▪ Citizens act as trustees, safeguarding biodiversity and preventing ecological degradation ▪ State retains ownership of natural resources while ensuring access to safe and adequate water[2] ▪ Specifically: - Article 5.1. on intergenerational trustee principles - Article 5.3. on 60% forest cover at all times - Article 5.2. to prevent pollution and ecological degradation and secure ecologically balanced sustainable development	Applicable The Constitution establishes the base line for the project in respect to its impact on the surrounding environment. These constitutional provisions inform the Project's environmental assessment framework, including biodiversity conservation, environmental flow management, pollution prevention, compensatory afforestation, and sustainable hydropower development.
B. ENVIRONMENTAL MANAGEMENT, BIODIVERSITY AND NATURAL RESOURCES		
Forest and Nature Conservation Act, 2023 and Amendment 2025	▪ Mandates a minimum of 60% forest cover to ensure sustainable management of forests, biodiversity, and natural resources. ▪ Requires prior clearance from DoFPS for activities on State Reserved Forest Land (SRFL) ▪ Imposes strict restrictions in critical watersheds, protected areas, wetlands, water bodies, and near cultural sites ▪ Prohibits mining, quarrying, and harmful development in core zones and regulates protected species under revised Schedules I–III	Applicable Because forest or forest land is needed for the Project, environmental protection and compensation are required. Schedule I to III species are / may be present at the Project's Area of Influence. Protection dispositions of the Act apply.

[2] Right to property: a Bhutanese citizen has the right to own property pursuant to the Constitution of the Kingdom of Bhutan, Article 7(9). State ownership of natural resources: the State retains ownership of natural resources as provided under the Water Act of Bhutan, 2011, Section 5(a).

Legal Document	Summary Description	Applicability to the Project
	▪ Ensures compensatory measures, preventive actions, and fair compensation for community forests taken for national development.	
Environmental Assessment Act, 2000	▪ Environmental clearance required before issuance of development consent ▪ Government projects are exempt from development consent but still require environmental clearance ▪ Developers to include potential environmental impacts in applications for competent authority review ▪ Secretariat screens projects not listed to ensure sufficient information for impact assessment ▪ Applicants to prepare environmental assessment documents if information is inadequate and consult relevant stakeholders before submission ▪ Environmental clearance granted if impacts acceptable stakeholders' interests considered and project aligns with sustainable development and environmental commitments	Applicable Environmental or ESIA clearance is required Details - see Chapter Permits and Approvals
National Environment Protection Act, 2007	▪ Establishes policies, standards, and principles for forest governance and environmental management ▪ Mandates the Commission to prevent environmental harm and pollution ▪ Regulates hazardous substances, pollutant discharge, waste management and environmental emergencies ▪ Provides for protection of forests, biodiversity, ecosystems, and genetic resources ▪ Environmental financing and incentives to support conservation and protection efforts	Applicable Project environmental compliance, protection of the forest, minimizing adverse impacts on the environment and managing hazardous substances during the construction period
Biodiversity Act, 2022	▪ Secures economic value of Bhutan's biological and genetic resources for development and conservation	Applicable Protects the economic value of genetic resources

Legal Document	Summary Description	Applicability to the Project
	▪ Promotes sustainable use in research and product development. ▪ Regulates access and utilization of genetic resources and associated traditional knowledge ▪ Ensures responsible management and equitable benefit-sharing.	
Water Act of Bhutan, 2011	▪ Prohibits water abstraction or use without Environmental Clearance ▪ Prioritizes water use for drinking and sanitation, followed by agriculture, energy, industry, tourism, and other uses, with flexibility in emergencies ▪ Supports coordinated management and efficient utilization under the national IWRM Plan ▪ Requires registration of water use permits, abstraction, and effluent discharge with annual reporting to the Commission	Applicable
Water Regulation of Bhutan, 2014	▪ Ensures fish movement and sustains water ecology, including minimum environmental flows ▪ Applies Polluter Payer and User Payer principles ▪ Restricts development within 100 feet of high flood levels unless Environmental Clearance is obtained ▪ Requires consultation with existing water users and technical assessment by Dzongkhag for new water use ▪ Dams without fish passage to explore retrofitting to allow fish movement	Applicable The Water Regulation states that if a dam lacks a fish passage design, the Competent Authority may require the project authority to explore retrofitting the dam with fish passage or other measures to allow fish movement.
Forest and Nature Conservation Rules and Regulations (FNCRR), 2023	▪ Requires detailed project/feasibility report for forestry clearance in State Reserved Forest Land ▪ Tree cutting needs valid permit and hammer mark ▪ Collection/trade of Schedule I–III wild plants and fauna regulated; permits and scientific recommendations required ▪ Department manages invasive/exotic species per Biodiversity Act	Applicable

Legal Document	Summary Description	Applicability to the Project
	▪ Fishing in State Reserved Forest Land is regulated and classified by the Department ▪ Afforestation, reforestation, and soil conservation to follow Technical Guidelines ▪ Department oversees waste management, coordination, and disposal in State Reserved Forest Land	
Biodiversity Rules and Regulations, 2023	▪ National Biodiversity Centre (NBC) is the focal point for implementation and international representation ▪ NBC serves as the clearing house and national repository for genetic resources ▪ Act and Regulation focus on genetic resource conservation but exclude species and ecosystem diversity	Applicable
Environmental Standards, 2020	▪ Sets criteria and permissible limits for water, air, and noise quality ▪ Regulates industrial and STP effluent discharge ▪ Covers emissions from industries, vehicles, aluminum smelting, and incineration ▪ Specifies standards for workplace air quality and waste incinerator ash disposal.	Applicable HPP and construction - related environmental standards to be met (overview on Chapter 2.8)
Bhutan Drinking Water Quality Standard, 2016	▪ Ensures safe drinking water and protects public health ▪ All parties to adhere to water quality parameters per WHO Guidelines ▪ Surveillance Body to notify providers for corrective action in case of non-compliance, under the Water Act 2011 and Water Regulation 2014	Applicable Project to ensure water quality parameters
Waste Prevention and Management Act of Bhutan, 2009	▪ Protects human health by minimizing waste, promoting reuse/recycling and ensuring environmentally sound disposal ▪ Supports sustainable development and intergenerational equity, balancing environmental conservation with economic growth	Applicable

Legal Document	Summary Description	Applicability to the Project
	▪ Requires waste-generating activities to align with Bhutan's ecological and geographical constraints ▪ Implements the Polluter Pays Principle, holding polluters accountable for prevention, mitigation and remediation costs	
Waste Prevention and Management Regulation, 2012	▪ Hazardous waste can be exported only with importing country consent and compliance with safety standards ▪ Sanitary landfills/open dumps to be located away from settlements, water sources, landslide zones, endangered species habitats, and cultural sites ▪ Implementing agencies to ensure safe handling, storage, transport, pre-treatment, PPE use, signage, and record-keeping for hazardous waste ▪ Waste categorized into industrial, e-waste, and construction waste and proper disposal and segregation are required ▪ Construction and industrial sectors are responsible for on-site waste management, safe transport and maintaining clean premises.	Applicable
Regulation for Environmental Clearance of Projects, 2016	▪ While the 2001 RECOP established the initial procedures, it has since been superseded by the 2016 RECOP, which is the currently applicable legal instrument.	Applicable It guides DGPC in integrating environmental considerations into the planning and implementation stages
C. HYDROPOWER, INFRASTRUCTURE AND RESOURCE DEVELOPMENT		
Electricity Act of Bhutan, 2001	▪ Integrates environmental considerations into electricity development ▪ Ensures protection of natural resources, the environment, and public interests ▪ Set objectives to develop the socio-economic welfare of the people	May be applicable Ensures protection of natural resources and consideration of social, cultural, and recreational factors during the project planning, construction, and operation

Legal Document	Summary Description	Applicability to the Project
	▪ Factors to be considered for an application, such as the impact of the operation of the undertaking on the social, cultural, and recreational life of the community	
Mines and Minerals Management Act (MMMA), 1995	▪ The Act governs the development of all minerals in line with RGoB policies, ensuring efficient use, environmental protection, and worker/public safety ▪ Provides for environmental standards and natural resource conservation. ▪ No compensation for immovable property or infrastructure in mining areas is mandated, unless specified in lease agreements	Applicable ▪ The MMMA 1995 is highly relevant to the Bunakha HPP primarily because of the Project's massive demand for construction materials and the necessary excavation work. ▪ DGPC or the Construction Contractor must obtain a Quarrying Lease from the Department of Geology and Mines (DGM) ▪ The management and disposal or use of the excavated material (which are mineral resources) must comply with the environmental and geological standards set by the DGM. ▪ Quarrying and excavation sites for the HPP must have approved Environmental Management Plans (EMPs) and comply with Occupational Health and Safety (OHS) standards for the safe use of explosives and operation of mines.
Mines and Minerals Bill of Bhutan, 2020	The Bill establishes the legal framework for the regulation, management, exploration, extraction, and sustainable utilization of mineral resources in	Applicable The Bill is relevant to the Bunakha HPP as construction activities may

Legal Document	Summary Description	Applicability to the Project
	Bhutan. It promotes responsible and environmentally sustainable mining practices, strengthens regulatory oversight, and provides procedures for licensing, extraction, quarrying, mine restoration, and management of construction materials. The Bill seeks to ensure that mineral resources are developed in a transparent, accountable, and environmentally sound manner.	require extraction, procurement, or use of construction materials such as stone, aggregates, sand, and gravel from approved quarries or borrow areas. Any project-related quarrying, material sourcing, or disposal of excavated rock materials shall comply with applicable mining and quarrying requirements, licensing procedures, environmental safeguards, and site restoration obligations prescribed under the legislation.
Road Act of the Kingdom of Bhutan, 2013	▪ Applies to the construction of access roads, requiring compliance with prescribed standards ▪ Department of Surface Transport (DoST) oversees national roads; Thromde, Dzongkhag, and Gewog manage local roads ▪ DGPC to submit road plans and specifications to DoST or local authorities for approval	Applicable
Road Safety and Transport Regulations, 2021	▪ Vehicles to meet Pollution Under Control (PUC) emission standards ▪ Drivers to obtain a valid PUC certificate as proof of emission testing ▪ Vehicles to have securely fitted silencing devices to control exhaust noise ▪ Noise from vehicles not to exceed permissible levels set by the NEC	Applicable
D. LAND ACQUISITION, COMPENSATION AND RESETTLEMENT		
Land Act of Bhutan, 2007	▪ Legally sound and constitutionally compliant framework for compulsory land acquisition for public interest projects, emphasizing procedural fairness and robust compensation mechanisms.	Applicable

Legal Document	Summary Description	Applicability to the Project
	▪ Sets the right to registered land - The *Land Act of Bhutan, 2007*, Section 86, recognizes the right to registered land. - Land registered in the Thram (Land Registry Record) in the name of an individual shall belong to that individual. ▪ Sets the right to transact land - Under Section 93 of the *Lands Act of Bhutan, 2007*, a person owning an independent Thram has the exclusive right to transact his or her land. - Includes the right to surrender land to the Government, subject to the provisions of the Act. ▪ Section 22 defines ownership ▪ Section 25 entitlement to own land and is restricted to Bhutanese citizens only ▪ Section 28 provides for requirement for landownership certificate (*Lag-thram*) ▪ Manages acquisition and allocation of registered land to government institutions ▪ Approves acquisition of privately registered land - Acquires land in the public interest following established procedures, avoiding religious sites ▪ Provides fair compensation via cash or substitute land, including for properties and remaining small parcels ▪ Compensation determined by the Property Assessment and Valuation Agency, revised every three years ▪ Acquisition finalized only after registering substitute land or providing cash compensation	
Land Lease Rules and Regulations (LLRR), 2018	▪ Largely supersedes the Rules and Regulations for Lease of Government Reserved Forest Land & Government Land (RRLGRF), 2009. ▪ Regulates leasing of land (public or private) for hydropower, renewable	Applicable The LLRR 2018 is the definitive rulebook for leasing land for Bhutan's strategic energy projects,

Legal Document	Summary Description	Applicability to the Project
	energy, and associated transmission systems ▪ Agencies can assess private and public land for project development ▪ Project proposals and identified land require NLCS (National Land Commission Secretariat) review and consent ▪ Leases processed through Dzongkhag Land Record Office; period fixed by NLCS in consultation with the Agency ▪ Submerged land may be leased per project design; leases executed for construction period, with new lease upon commissioning ▪ Underground caverns/tunnels generally not leased except for permanent access, NLCS approval may be needed ▪ Same lease process applies for transmission towers and buffer areas as generation project	with the National Land Commission Secretariat (NLCS) holding the ultimate approving and record-keeping authority.
Land Exchange Rules and Regulations of Bhutan, 2022	▪ Governs procedures for land exchange (not acquisition) in Bhutan ▪ Ensures compliance with legal, administrative, and planning requirements. ▪ Provides framework for fair valuation, compensation, and registration of exchanged land	Applicable The Rules are enacted pursuant to the Land Act of Bhutan, 2007 ensuring all land exchanges are legal and adhere to government planning requirements.
Land Acquisition and Compensation Rules and Regulations, 2022	▪ Land acquisition requires prior compensation or land substitution ▪ Small parcels (<10 decimals) may be acquired or merged with adjoining state land ▪ Land valuation follows official rates by the Property Assessment Valuation Agency and Bhutan Schedule Rate	Applicable The LACRR 2022 is essential for any government or SOE projects (like HPPs) that require the permanent use of private registered land.
Land Compensation Rates, 2022	▪ Compensation for buildings/structures based on full replacement cost without depreciation. ▪ NLCS approval required for land acquisition proposals ▪ Landowners to be notified in advance	Applicable The Land Compensation Rates, 2022, and the associated Land Acquisition and Compensation Rules and

Legal Document	Summary Description	Applicability to the Project
	▪ Option for replacement land under Land Act 2007 or monetary compensation at government rates ▪ Structure valuations prepared by qualified engineers and verified by relevant committee.	Regulations, 2022, are the legal basis for all land and property acquisition and compensation thereof.
The Local Government Act of Bhutan, 2009	▪ Enables Local Governments to conserve the environment, protect public health and promote socio-economic development ▪ Dzongkhag Tshogdu regulates public health, safety, and environmental quality, including water, air and noise pollution ▪ Thromde Tshogde enforces local rules, manages land use, building activities and urban development while preserving environmental quality ▪ Requires national agencies to consult and involve Local Governments in planning and implementing projects ▪ Thromde Administration oversees local planning, development priorities and environmental management to protect public health and safety ▪ Approve the purchase, lease, acquisition, or disposal of land and property in the interest of the Thromde, in accordance with the policies of the Royal Government.	Applicable. The Local Government Act is relevant to the Bunakha HPP because implementation of the Project will require continuous coordination between DGPC and local government authorities, including Chhukha Dzongkhag Administration, Gewog Administrations, elected local representatives, and relevant sectoral agencies. Local authorities will support stakeholder engagement, land acquisition and leasing processes, disclosure activities, grievance resolution, implementation of local development initiatives, emergency preparedness arrangements, and coordination of project-related activities within their respective jurisdictions. DGPC will maintain regular coordination with Dzongkhag and Gewog authorities throughout project implementation.
E. LABOUR, OCCUPATIONAL HEALTH AND FOREIGN WORKER MANAGEMENT		
Labour and Employment Act of Bhutan, 2007	▪ Prohibits forced or compulsory labor and the worst forms of child labor, including hazardous or abusive work	Applicable

Legal Document	Summary Description	Applicability to the Project
	▪ Require employers to ensure occupational health and safety, identify hazards, provide training, and maintain a safe work environment ▪ Mandates compensation for workplace accidents and occupational diseases, except in cases of willful negligence ▪ Obligates monitoring, record-keeping, and confidential sharing of workplace health and safety information	
Regulation on Occupational Health, Safety and Welfare, 2022	Establishes requirements for workplace health, safety, and worker welfare, including hazard management, use of PPE, worker training, incident reporting, emergency preparedness, and provision of welfare facilities.	**Applicable.** The Project must ensure safe working conditions for all workers during construction and operation through the implementation of OHS measures, the provision of PPE, safety training, emergency response procedures, and compliance with occupational health and welfare requirements.
Regulation on Working Conditions, 2022	▪ Applies to all workplaces under the Labour and Employment Act, 2007 ▪ Ensures good working conditions for project workers	Applicable
Immigration Act of Bhutan and Foreign Worker Regulations	• Regulates the entry, residence, employment authorization, work permits, monitoring, and departure of foreign nationals employed in Bhutan. • Establishes requirements for visas, work permits, registration, compliance monitoring, and enforcement of immigration procedures.	Applicable The legislation is relevant to engagement of foreign workers, technical specialists, and contractor personnel during Project construction and operation. All foreign personnel engaged by the Project shall obtain required visas, work permits, and employment authorizations and comply with applicable immigration, labour, health, and security

Legal Document	Summary Description	Applicability to the Project
		requirements established by the Royal Government of Bhutan.
Regulation on Foreign Workers Management, 2024	• Supersedes the 2022 version; employers must ensure foreign workers' conditions comply with the Labour and Employment Act, 2007, and related regulations	Applicable Specialist tasks will need to be completed by foreign workers on this project and these workers will have to comply under this act.
F. SOCIAL INCLUSION, VULNERABLE GROUPS AND COMMUNITY PROTECTION		
Child Care and Protection Act of Bhutan	The Act provides for the protection, welfare, and development of children and establishes measures to safeguard children from abuse, exploitation, neglect, violence, and harmful practices.	Applicable. The Project will prohibit child labour, implement child safeguarding measures, and ensure that project activities do not expose children to increased risks. Relevant provisions have been incorporated into the Labour Management Plan, Code of Conduct, and Stakeholder Engagement Plan.
Domestic Violence Prevention Act of Bhutan	The Act establishes measures for prevention of domestic violence and protection of victims, including women and vulnerable persons.	Applicable. The Project recognizes the potential risks associated with labour influx and social change during construction. Measures addressing gender-based violence, sexual exploitation, abuse and harassment (SEAH), and protection of vulnerable groups have been incorporated into project management plans and contractor requirements.
Penal Code of Bhutan	▪ Establishes criminal offences and penalties relating to sexual offences, harassment, assault, trafficking, exploitation, violence against women and children, and other offences affecting public safety, welfare, and individual rights.	Applicable The Penal Code is relevant to labour influx management, worker conduct, prevention of gender-based violence (GBV), sexual exploitation,

Legal Document	Summary Description	Applicability to the Project
	▪ Provides legal sanctions against sexual harassment, sexual exploitation, abuse, violence, trafficking, child abuse, and other forms of misconduct.	abuse and harassment (SEAH), child protection, community health and safety, and enforcement of worker Codes of Conduct. All Project personnel and contractors shall comply with applicable provisions of the Penal Code of Bhutan.
G. CULTURAL HERITAGE AND RELIGIOUS RESOURCES		
Movable Cultural Property Act of Bhutan, 2005	▪ Protects Bhutan's movable cultural property ▪ Requires reporting of valuable cultural items if found during construction	Applicable Responsibility during the design to avoid impacting cultural property and during construction in case of movable items found
Religious Organization Act of Bhutan, 2007	▪ Ensures religious structures comply with traditional and cultural designs ▪ Indirectly supports protection of cultural and religious sites relevant to project planning	Applicable Project's need for coordination with local government authorities and the presence of religious, cultural, and heritage resources within the Area of Influence.
Cultural Heritage Bill of Bhutan, 2016	▪ The Cultural Heritage Bill provides a framework for the identification, protection, conservation, management, and promotion of Bhutan's cultural heritage, including both tangible and intangible cultural heritage resources. The Bill recognizes the importance of community participation and consultation in the protection of cultural heritage values. ▪ Dzongkhag and Thromde administrations to integrate cultural heritage preservation in development rules and plans ▪ Requires local community consent for activities affecting cultural elements before permit application	Applicable. The Project Area of Influence contains cultural, religious, and landscape features of local significance. Although no direct impacts on major cultural heritage sites are anticipated, project activities have the potential to affect access, setting, cultural practices, or undiscovered heritage resources. Therefore, the principles embodied in the Cultural Heritage Bill have been considered in the ESIA process and are reflected in the Cultural

Legal Document	Summary Description	Applicability to the Project
	▪ Large-scale projects to obtain development permits and cultural landscape clearance from DCDD ▪ Cultural Heritage Committee may define buffer zones around heritage sites ▪ Prior DCDD approval required for work on important cultural or archaeological sites	Heritage Management Plan, stakeholder engagement activities, chance-find procedures, and consultation with affected communities and relevant authorities.
H. DISASTER MANAGEMENT AND PUBLIC ADMINISTRATION		
Disaster Management Act, 2013	▪ Establishes and strengthens institutional capacity for disaster management and risk reduction ▪ National Disaster Management Authority (NDMA) is apex disaster management body and Dzongkhags to form Disaster Management Committees and to coordinate local disaster operations ▪ Department of Disaster Management (DODM) acts as NDMA secretariat and coordinating agency	May be applicable/ conditional
Public Finance Act of Bhutan, 2007	▪ Establishes and strengthens institutional capacity for disaster management and risk reduction ▪ National Disaster Management Authority (NDMA) is apex disaster management body and Dzongkhags to form Disaster Management Committees and to coordinate local disaster operations ▪ Department of Disaster Management (DODM) acts as NDMA secretariat and coordinating agency	May be applicable/ conditional

2.3 National Institutional Framework

An overview of the national institutions with a stake in the Project is provided in Table 5.

Table 5: National institutional framework of relevance to the Bunakha HPP

Institution	Summary description	Stake in the Project
Ministry of Energy and Natural Resources (MoENR)	▪ Formulating national energy policies, strategies, and guidelines to promote sustainable energy development. ▪ Provides regulatory oversight for hydropower and renewable energy projects ▪ Project facilitation and development by issuing clearances, coordinating with implementing agencies	Policy Leadership Key stake in the Energy Sector
National Environment Commission	▪ NEC Secretariat an autonomous advisory body to the Royal Government of Bhutan on environmental matters ▪ Serves as the custodian of the Environmental Assessment Act, 2000 ▪ Mandated to integrate natural resource sustainability into national social and economic development ▪ Responsible for implementing national environmental policies and programs ▪ Acts as the focal agency for international environmental conventions	Key stake
Department of Environment and Climate Change (DECC)	▪ Coordinating national waste management initiatives ▪ Supporting climate change adaptation and loss-and-damage readiness ▪ Facilitating environmental policy implementation ▪ Strengthening national capacity for sustainable development in collaboration with government agencies, development partners, and local authorities.	Key stake
Department of Energy	▪ Responsible for power sector policy, planning, and regulation under the Ministry of Energy and Natural Resources (MoENR) ▪ Oversees generation, transmission, distribution, and project implementation ▪ Conducts investigations and feasibility studies for hydropower projects ▪ Develops policy guidelines to promote the participation of independent power producers and operators	Administrative stake
Department of Forests and Park Services	▪ Departments operate under the Ministry of Energy and Natural Resources (MoENR) ▪ Responsible for managing forest resources and biodiversity ▪ Ensures at least 60% of Bhutan's land remains under forest cover	Administrative stake

Institution	Summary description	Stake in the Project
	▪ Conserves biodiversity through a network of protected areas ▪ Grants clearance for projects affecting forestland	
Department of Geology and Mines	▪ Responsible for geological surveys, planning, and mineral exploration under the Ministry of Energy and Natural Resources (MoENR) ▪ Monitors glacial lakes and potential outburst threats ▪ Custodian of the Mines and Minerals Management Act, 1995 ▪ Issues clearances for quarry site operations	Operational stake
Department of Surface Transport	▪ Responsible for planning and constructing Bhutan's road network under Ministry of Infrastructure and Transport ▪ Custodian of the Road Act, 2004. ▪ Issues clearance for access roads to hydropower sites required for Environmental Clearance	Operational stake
Druk Green Power Corporation	▪ Druk Green Power Corporation Limited (DGPC), a subsidiary of Druk Holding and Investments Limited ▪ DGPC as electricity generation company mostly in HPP ▪ DGPC is the primary agency responsible for coordinating land acquisition, land leasing, compensation, and resettlement implementation with relevant national and local government authorities	Key stake
Chhukha Dzongkhag	▪ Chhukha Dzongkhag is divided into 11 Gewogs, each headed by an elected Gup. ▪ Gups, members of the District Yargay Tshogdu (DYT)- the chair is elected from among them. ▪ Dzongdag (District Administrator) has observer status in the DYT. ▪ Project area falls in Chapcha and Geling Gewogs and projects within the Dzongkhag to coordinate with Gewogs and the DYT for implementation.	Operational stake
National Commission for Women and Children (NCWC)	▪ The NCWC is the national agency responsible for promoting and protecting the rights and wellbeing of women and children in Bhutan. ▪ The Commission develops policies, coordinates safeguarding initiatives, and supports implementation of measures related to gender equality,	The NCWC provides the national policy framework relevant to gender equality, prevention of gender-based violence, prevention of sexual exploitation, abuse and harassment (SEAH), child protection, and protection of vulnerable groups. The Project's Gender and

Institution	Summary description	Stake in the Project
	prevention of violence, child protection, and social inclusion.	Vulnerability Action Plan, Labour Management Plan, Workers' Code of Conduct, and SEAH prevention measures are aligned with these national objectives.
Pema Secretariat	▪ The Pema Secretariat serves as Bhutan's national coordinating mechanism for disability inclusion and supports implementation of disability-related policies and programs. It promotes accessibility, inclusion, and protection of the rights of persons with disabilities.	The Pema Secretariat provides policy guidance relevant to inclusion of persons with disabilities in project consultation, information disclosure, grievance management, emergency preparedness, and access to project benefits. The ESIA recognizes persons with disabilities as a potentially vulnerable group requiring specific consideration during project implementation.

In addition to environmental, forestry, water, and infrastructure-related institutions, several national agencies play an important role in promoting social inclusion, gender equality, protection of vulnerable groups, and safeguarding of human rights. These include the National Commission for Women and Children (NCWC), which provides policy leadership on gender equality, child protection, prevention of gender-based violence, and protection from sexual exploitation, abuse, and harassment (SEAH), and the Pema Secretariat, which supports implementation of disability-inclusive policies and programmes in Bhutan.

The principles and policy guidance provided by these institutions have informed the preparation of the Project's social safeguard instruments, including the Resettlement Plan (RP), Stakeholder Engagement Plan (SEP), Gender and Vulnerability Action Plan (GVAP), Labour Management Plan (LMP), Grievance Redress Mechanism (GRM), and SEAH prevention measures. During Project implementation, DGPC and contractors will ensure that project activities are undertaken in a manner consistent with national requirements relating to gender equality, child protection, disability inclusion, and support for vulnerable groups.

2.4 National Technical Guidelines

The key guideline documents with ESIA- and Project-relevance are described in Table 6 together with their applicability to the Project.

Table 6: Technical guidelines of relevance to the Bunakha HPP

Guideline document	General description	Applicability to the Project
Bhutan Hydropower Guidelines, 2018 (rev. 2024)	The DoE under the Ministry of Energy and Natural Resources is the designated agency for receiving and approving DPRs for all HPPs in Bhutan (Section 9). The Guideline ensures the DPRs comply with the guidelines, facilitate necessary sectoral clearances, and coordinate approvals from other government agencies. DHPS may request additional information or clarification from applicants and holds the authority to approve, reject, suspend, or cancel submissions. The DHPS will also issue updates on any changes in policy or amendments to the guidelines.	Applicable Regulates the approval process and authority of DoE/DHPS on Project compliance, coordination and governance
EA Guideline for Hydropower 2012	The Guideline advises that an EIA should not be seen just as a formality for getting approval, but as a useful tool for planning sustainable hydropower projects (Section 1.4). Project implementers should use it to improve project planning, while authorities should make sure the project causes less harm to the environment and brings more social and economic benefits. Impacts due to hydropower projects such as aspects of environment, water resources & water quality, biodiversity, aquatic and terrestrial ecology, socio-economic aspects, air and noise pollution and public health issues has to be addressed (Section 1.5).	Applicable Provides environmental considerations, sustainability measures and Project planning tools
Guideline to Determine Minimum Environmental Flow Regulations for Dewatered Reaches of Hydropower Projects in Bhutan, 2019	The main goal of setting environmental flow regulations is to protect aquatic ecosystems affected by hydropower by maintaining natural water and sediment flows that support biodiversity and ecosystem services. While fish are important, other species, as well as social, cultural, and economic factors, must also be considered. Environmental flows to be linked with allowing fish to move freely upstream and downstream of dams. However, ensuring these flows can reduce hydropower output, creating a challenge for decision-makers to balance environmental protection with economic benefits (Section 1.4).	Applicable Provides environmental, social, cultural and economic safeguards, ecosystem management and sustainability considerations Defines the role of environmental flows in mitigating ecological impacts

Guideline document	General description	Applicability to the Project
Rehabilitation and Resettlement (R&R) Guideline for Hydropower Projects	The Rehabilitation and Resettlement (R&R) Guideline for Hydropower Projects has not been launched yet. Instead, Bhutan primarily relies on its Land Acquisition and Compensation Rules and Regulations, 2022 (LACRR 2022) and the Land Act of Bhutan, 2007 .	

2.5 International Framework

Bhutan is a Party to a range of international environmental, social, cultural, and human rights conventions that are relevant to the BHPP. These international commitments complement national legislation and provide important principles for environmental protection, biodiversity conservation, cultural heritage preservation, gender equality, protection of vulnerable groups, labour standards, and social inclusion.

In addition to environmental conventions addressing biodiversity, climate change, and natural resource management, the Project has considered international commitments relating to the rights of women, children, persons with disabilities, and protection of tangible and intangible cultural heritage. These commitments have informed the preparation of the Environmental and Social Impact Assessment (ESIA), Resettlement Plan (RP), Stakeholder Engagement Plan (SEP), Gender and Vulnerability Action Plan (GVAP), Labour Management Plan (LMP), and other environmental and social management measures associated with the Project.

The following international conventions and frameworks are considered relevant to the Project and have been reviewed as part of the ESIA process.

2.5.1 International conventions

Bhutan has ratified most of the conventions internationally regulating protection of the environment and of which the most important are described in Table 7.

Table 7: International conventions of relevance to the Bunakha HPP

International Convention	Brief description	Applicability to the Project
United Nations Framework Convention on Climate Change (UNFCCC), 1992	▪ Climate change mitigation and adaptation. ▪ Signed the UNFCCC in 1992 and ratified on 25 August 1995	Applicable Project limits greenhouse gas (GHG) emissions and promotes climate-resilient development as a renewable energy source
Kyoto Protocol, 1997	▪ Commitments under UNFCCC for reducing greenhouse gas emissions ▪ Ratified the Kyoto Protocol on August 26, 2002	Applicable Project consists of renewable (virtually) emission-free energy generation under the Protocol's climate mitigation and clean development framework

International Convention	Brief description	Applicability to the Project
Paris Agreement, 2015	▪ Successor to the Kyoto Protocol, focusing on global climate action. ▪ Signed the Paris Agreement on April 22, 2016 and ratified on September 19, 2017	Applicable The agreement emphasizes Nationally Determined Contributions (NDCs) to maintain net-zero greenhouse gas emissions by promoting renewable hydropower development
Vienna Convention for the Protection of the Ozone Layer, 1985	▪ Vienna Convention provides a global framework for protecting the ozone layer ▪ Promotes international cooperation and information exchange on ozone protection ▪ Acceded to the Convention on 23 August 2004	Not applicable The Bunakha HPP does not directly emit ozone-depleting substances
Montreal Protocol on Substances that Deplete the Ozone Layer, 1987	▪ Montreal Protocol regulates production and use of ozone-depleting substances (ODS) ▪ Successfully protects and restores the ozone layer ▪ Acceded on 23 August 2004.	
The Kigali Amendment to the Montreal Protocol, 2016	▪ Kigali Amendment adopted to phase down hydrofluorocarbons (HFCs) by 80–85% by the 2040s ▪ Bhutan ratified the Kigali Amendment on 27 September 2019	
Convention on Biological Diversity (CBD), 1993	▪ Conservation of biodiversity and sustainable use of biological resources ▪ Bhutan ratified the Convention on Biological Diversity (CBD) on 25 August 1995	Applicable Project planning and implementation incorporates environmental impact assessment, mitigation measures and conservation strategies to minimize impacts on flora, fauna, and ecosystems Project aligns with the commitment on protection and sustainable management of biological diversity
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973	▪ Protection of endangered species from illegal as the core objective of CITES, it uses a licensing system based on three Appendices (I, II, and III) to regulate trade in species threatened by extinction (Appendix I) or those that might become threatened without trade regulation (Appendix II). ▪ Bhutan acceded on 15 August 2002	Applicable Trading on endangered species during project construction or due to the improved access to a previously virtually inaccessible forest area may increase the opportunistic trade in endangered species. The ESMP shall strictly forbid this; any illegal trading activities shall be

International Convention	Brief description	Applicability to the Project
		monitored during implementation
Ramsar Convention, 1971	▪ Protection and sustainable use of wetlands ▪ Bhutan acceded to the Convention on 7 May 2012	Not applicable After the Convention was officially entered into force in September 7, 2012, Bhutan is committed to the 'wise use' of all wetlands within its territory and to the preservation of its designated Wetlands of International Importance: Bumdeling, Khotokha, and Gangtey-Phobji Valley. None of these sites is located within the Bunakha HPP's Area of Influence.
Basel Convention, 1989	▪ Control of transboundary movement of hazardous waste ▪ Bhutan acceded on 26 August 2002	Applicable The Project may generate construction-related hazardous waste that shall be managed (also) in accordance with this convention
Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW)	Bhutan acceded to CEDAW in 1981. The Convention promotes gender equality and elimination of discrimination against women in political, social, economic, and cultural life.	Applicable. The Project incorporates gender-responsive consultation, employment opportunities, grievance management, and implementation of the Gender and Vulnerability Action Plan.
Convention on the Rights of the Child (CRC)	Bhutan ratified the CRC in 1990. The Convention protects the rights, welfare, and development of children.	Applicable. The Project will implement child protection measures, prohibit child labour, and incorporate child safeguarding provisions in contractor management procedures.
Convention on the Rights of Persons with Disabilities (CRPD)	Bhutan ratified the CRPD in 2023. The Convention promotes equal rights and inclusion of people with disabilities.	Applicable. Project consultation, information disclosure, grievance management, and emergency preparedness measures will consider the needs of persons with disabilities.
Convention for the Safeguarding of the Intangible Cultural Heritage (UNESCO, 2003)	The Convention promotes identification, documentation, protection, and transmission of intangible cultural heritage, including traditional practices, knowledge, rituals, and cultural expressions	Applicable. The Project will consider both tangible and intangible cultural heritage resources through the Cultural Heritage Management Plan and stakeholder engagement process.

Collectively, these international commitments provide a framework for promoting environmental sustainability, protection of biodiversity, social inclusion, gender equality, protection of vulnerable groups, preservation of cultural heritage, and respect for human rights throughout the Project lifecycle. The principles embodied in these conventions have been integrated into the Project's environmental and social management measures, stakeholder engagement processes, labour management provisions, grievance mechanisms, and monitoring arrangements.

2.5.2 Asian Development Bank's Safeguard Policy Statement (2009)

The Asian Development Bank (ADB) adopted its Safeguard Policy Statement (SPS) to establish a robust framework aimed at avoiding, minimizing, or mitigating adverse environmental and social impacts while ensuring the protection of affected communities during the development process. The SPS is supported by an Operations Manual specifying internal safeguard review, monitoring and reporting procedures at each stage of the project cycle. ADB does not invest in projects that fail to comply with its safeguard policies or with the host country's environmental and social laws and international obligations (paragraph 47, SPS).

ADB's SPS sets out the policy objectives, scope and triggers, and principles for three key safeguard areas: (i) environmental safeguards, (ii) involuntary resettlement safeguards, and (iii) Indigenous Peoples safeguards. To help borrowers/clients and their projects achieve the desired outcomes, ADB adopts a set of specific safeguard requirements that borrowers/clients are required to meet:

- Safeguard Requirements 1: Environment
- Safeguard Requirements 2: Involuntary Resettlement
- Safeguard Requirements 3: Indigenous Peoples
- Safeguard Requirements 4: Special Requirements for Different Finance Modalities.

ADB's Safeguard Requirements follow a structured process of impact assessment, planning, and mitigation throughout the project lifecycle. This ensures that potential adverse impacts are identified early, appropriate mitigation measures are developed and implemented, and affected communities are informed and consulted during both the preparation and implementation phases (paragraph 15, SPS). The primary responsibility for implementing these safeguards lies with the borrower or client, who must conduct assessments, engage stakeholders, prepare and execute safeguard plans, monitor and report to ADB on the progress and safeguard performance. ADB supports this process through guidance, capacity building, due diligence, continuous monitoring, and safeguards review missions (including project site visits). This is done during project implementation and through completion and evaluation reports (paragraph 16, SPS).

To ensure compliance, ADB has established a comprehensive monitoring system throughout the project cycle. The Head of Safeguards within the Environment and Social Safeguard Division provides advice on compliance matters, while operations departments ensure, through due diligence, that safeguard requirements are met prior to Board approval. Projects with potential noncompliance risks are reviewed in key management meetings, and compliance is further monitored through review missions during implementation to address emerging issues (paragraph 17, SPS).

Additionally, ADB has an Accountability Mechanism (AM) that allows persons adversely affected by ADB-financed projects to raise grievances, seek resolution, and report potential violations of operational policies, including safeguard policies (paragraph 18, SPS)[3].

2.5.2.1 Indigenous Peoples considerations

The SPS requires projects to respect the dignity, human rights, and cultural uniqueness of Indigenous Peoples (IPs). It seeks to avoid adverse impacts on these groups and, where avoidance is not possible, to minimize and mitigate impact while ensuring that the IPs communities benefit equitably from development initiatives.

Under the SPS, projects that may affect IPs must undergo early screening to determine the presence and potential impact on these communities. A thorough social impact assessment is required to understand how a project might impact their livelihoods, cultural practices, and access to land and resources. The policy requires meaningful consultation processes, ensuring that IPs are fully informed and able to participate in decisions that affect them. In certain cases—such as when projects involve relocation, commercial use of cultural resources, or impact on critical natural areas—Broad Community Support (BCS) must be obtained.

To ensure these safeguards, an Indigenous Peoples Plan (IPP) and/or an Indigenous Peoples Framework (IPF) - as applicable to the project or program - must be developed by the DGPC. These documents outline measures to mitigate negative effects and enhance positive outcomes, ensuring that development is culturally appropriate and inclusive. The SPS also requires monitoring mechanisms and establishing an accessible project-level grievance redress mechanism (GRM) to address project-related grievances.

2.5.2.1.1.1 Indigenous Peoples in Bhutan

On July 29, 2024 the Ministry of Foreign Affairs and External Trade of the Royal Government of Bhutan issued advises advice that the term 'Indigenous Peoples' is not applicable in Bhutan - see Annex 6. If development partners intend to refer to groups disadvantaged due to remoteness these can be identified as "disadvantaged or vulnerable groups". The Ministry of Finance is requested to inform development partners accordingly and encourage the use of terminology that aligns with Bhutan's context.

From an international perspective, and according to the ADB SPS (2009), there is no universally accepted definition of IPs[4]. For operational purposes, the term IPs is used by ADB in a generic sense to refer to a distinct, vulnerable, social and cultural group possessing all of the following characteristics in varying degrees:

- (i) self-identification as members of a distinct indigenous cultural group and recognition of this identity by others;
- (ii) collective attachment to geographically distinct habitats or ancestral territories in the project area and to the natural resources in these habitats and territories;
- (iii) customary cultural, economic, social, or political institutions that are separate from those of the dominant society and culture; and

[3] ADB's AM: https://www.adb.org/who-we-are/accountability-mechanism. Further details can be consulted **Error! Reference source not found.** of this ESIA Report.

[4] These groups may be referred to in different countries by such terms as indigenous ethnic minorities, indigenous cultural communities, aboriginals, hill tribes, minority nationalities, scheduled tribes, or tribal groups (ADB SPS, 2009)

- (iv) a distinct language, often different from the official language of the country or region.

The SPS adds that, in considering these characteristics, national legislation, customary law, and any international conventions to which the country is a party will be taken into account.

The site surveys, visits and consultations undertaken for the Bunakha HPP ESIA show that the Project-affected persons (APs) are not distinct from the mainstream population regarding culture, social, economical or political habits and organizations. The PAPs speak the same language as the remaining national population and are not nomadic. Besides, they own land and other properties that form the basis of their sustenance. 9 Therefore, it can be stated that no IPs live in the Project area and that ADB's Safeguard Requirements 3: Indigenous Peoples are not applicable.

2.5.2.2 Environmental considerations

The environmental provisions of the SPS require borrowers to identify and assess the significance of environmental impacts early in the project cycle. This includes examining project alternatives and preparing environmental management plans that outline mitigation measures, institutional responsibilities, and monitoring arrangements.

The SPS emphasizes meaningful consultation with affected communities, ensuring that relevant information is disclosed in accessible formats and languages. Depending on the project's potential impact, borrowers must prepare documents such as Initial Environmental Examinations (IEEs) or full Environmental Impact Assessments (EIAs), which are subject to ADB review and supervision throughout the project lifecycle

The SPS also introduces the concept of critical habitat, which includes areas of high biodiversity value and ecological importance. Projects that may affect such habitats must demonstrate that no measurable adverse impacts will occur and that appropriate mitigation and offset measures are in place. Additionally, the SPS prohibits activities that involve significant conversion or degradation of natural habitats unless there are no feasible alternatives and the project yields substantial environmental benefits.

The SPS also supports the strengthening and use of country safeguard systems, encouraging alignment with national laws and institutional frameworks where they meet ADB standards.

2.5.2.3 Resettlement considerations

The involuntary resettlement requirements of the SPS apply to both physical displacement—such as relocation or loss of shelter—and economic displacement, which includes loss of land, house, other assets, access to assets, income sources, or other means of livelihood due to involuntary land acquisition or restrictions on land use.

A key principle of the SPS is that involuntary resettlement should be avoided wherever feasible. If unavoidable, it must be minimized through careful project design and consideration of alternatives.

Any unavoidable impact should be mitigated and compensated, i.e., when displacement does occur, affected persons must be compensated at full replacement cost and assisted in improving or at least restoring their living standards, income levels, and production capacity. Compensation is not limited to those with formal legal rights to land; informal land users such as squatters and encroachers are also entitled to compensation and resettlement assistance. Specifically, the involuntary resettlement requirements apply to three types of displaced persons:

- persons with formal legal rights to land lost in its entirety or in part;
- persons who lost the land they occupy in its entirety or in part who have no formal legal rights to such land, but who have claims to such lands that are recognized or recognizable under national laws;
- persons who lost the land they occupy in its entirety or in part who have neither formal legal rights nor recognized or recognizable claims to such land.

The SPS requires the preparation of a detailed Resettlement Plan (RP) proportional to the scale and complexity of the resettlement impacts. The RP must include a full census of affected households (100% - PAPs), a socioeconomic profile of PAPs (sample basis will be applicable in case of a large number of project affected households - PAHs), an assessment of economic and physical displacement impacts, entitlements, and assistance measures, institutional arrangements, resettlement budget and funding source, grievance redress mechanism, meaningful consultation and disclosure, monitoring and reporting requirements, implementation timeline, and strategies for income restoration and relocation. Special attention must be given to vulnerable groups, including women, Indigenous Peoples, and the poor, ensuring that their specific needs are addressed.

Meaningful consultation is a cornerstone of the resettlement process. ADB SPS requires early and ongoing engagement with affected communities, ensuring that information is disclosed in accessible formats and that feedback is incorporated into project design and mitigation measures. The policy also requires the establishment of project-level grievance redress mechanisms to resolve complaints in a timely and transparent manner.

Institutional arrangements, resettlement budget, monitoring and reporting requirements must be clearly defined, including responsibilities for implementing resettlement activities, monitoring, and reporting. The SPS emphasizes the importance of building capacity within executing agencies and involving civil society organizations and affected persons in planning and implementation. A resettlement budget must be prepared, detailing costs for compensation, relocation, livelihood restoration, and monitoring, with clear sources of funding.

2.5.2.4 Applicability to the Bunakha HPP

The SPS, their objectives and their applicability for the Project are presented in Table 8.

Table 8: Safeguard Policy Statement of the Asian Development Bank (SPS, 2009) and its applicability to the Bunakha HPP

ADB SPS (2009) Component	Main topics	Applicability to the Bunakha HPP
Safeguard Requirement 1: Environment		
Environmental Screening & Categorization	Categorization of projects as A, B, C, or FI based on the significance of environmental impacts.	Applicable. The ADB has provisionally classified the project as Category A for environment and involuntary resettlement, indicating the likelihood of significant, diverse, and potentially irreversible environmental impacts.
Environmental Assessment (EIA or IEE)	Environmental impact assessment for Category A and initial environmental examination for Category B.	Applicable. The Project's approval is dependent on the elaboration of a nationally and internationally compliant E(S)IA study.
Environmental Management Plan (EMP)	Required plan addressing mitigation measures, environmental monitoring and reporting requirements, emergency response procedures, related institutional or organizational arrangements, capacity development and training measures, implementation schedule, cost estimates, and performance indicators, and, if required, compensatory measures (offset).	Applicable. The Project is expected to impact the environment and communities, for which an E(S)MP is developed.
Biodiversity & Natural Resources	Requirements to protect and conserve biodiversity, natural habitats, and ecosystem services.	Applicable. The Project is located in the proximity to natural protected areas and may affect biodiversity.
Pollution Prevention & Control	Requirements for managing emissions, effluents, waste, hazardous materials, resource efficiency, and GHG considerations.	Applicable. The construction and operation of the Project entails risks of air, soil and water pollution that must be adequately managed.
Health & Safety	Community and occupational health and safety requirements	Applicable.

ADB SPS (2009) Component	Main topics	Applicability to the Bunakha HPP
	during construction and operation.	The Project is located nearby villages, posing community H&S concerns; and will be built and operated by human workforce requiring H&S management procedures.
Physical Cultural Resources	Assessment and mitigation of impacts on cultural heritage.	Applicable. Chapter 7.3.8.1 - Religious, historical and cultural heritage sites lists resources that can be potentially affected by the Project.
Climate Change & Risks	Consideration of climate risks and impacts on project design (implied through environmental assessment requirements).	Applicable. See Chapter 9 - Climate Impact Assessment.
Safeguard Requirement 2: Involuntary Resettlement (IR)		
Screening & Categorization (IR)	Identification of project-induced physical or economic displacement; categorization.	Applicable. The ADB has provisionally classified the project as Category A for environment ,
Social Impact Assessment	Analysis of socio-economic impacts related to displacement and resettlement.	Applicable. See Chapter 11 - Social Impact Assessment.
Resettlement Plan (RP)	Preparation of a Resettlement Plan (not "LARP") when IR is triggered.	Applicable. See Annex 9 **Error! Reference source not found.**.
Meaningful Consultation	Consultation with displaced persons and disclosure of the RP.	Applicable. See Chapter **Error! Reference source not found. - Error! Reference source not found.** and Annex 10**Error! Reference source not found.**.
Compensation & Assistance	Compensation at replacement cost and livelihood restoration to at least pre-project levels.	Applicable. See Annex 9**Error! Reference source not found.**.
Special Assistance to Vulnerable Groups	Additional assistance to vulnerable displaced persons.	Applicable. See Annex 9**Error! Reference source not found.**.
Negotiated Land Acquisition	Encouraged where possible (voluntary / negotiated settlements).	Applicable. See Annex 9**Error! Reference source not found.**.

ADB SPS (2009) Component	Main topics	Applicability to the Bunakha HPP
Grievance Redress Mechanism (GRM)	Establishment of a functioning GRM for resettlement-related concerns.	Applicable. See Annex 9**Error! Reference source not found.**.
Monitoring & Reporting	Internal and, when required, external monitoring of RP implementation.	Applicable. See Chapter 14 - Environmental and Social Monitoring Programme.
Safeguard Requirement 3: Indigenous Peoples (IP)		
IP Screening	Identification of Indigenous Peoples impacts.	Not applicable. See Chapter 2.5.2.1.1.1 - Indigenous Peoples in Bhutan.
Indigenous Peoples Plan (IPP)	Preparation of IPP if required.	
Broad Community Support	Requirement for broad community support.	
Culturally Appropriate Benefits	Provision of benefits to IP communities.	
Consultation (IP)	Culturally appropriate consultation.	
GRM (IP)	Culturally appropriate grievance access.	
Monitoring (IP)	Monitoring of IPP implementation.	
Cross-Cutting SPS Requirements		
Information Disclosure	Disclosure of EIA/IEE, RP, and IPP documents.	Applicable. See **Error! Reference source not found. - Error! Reference source not found.**.
Meaningful Stakeholder Engagement	Continuous, inclusive, gender-responsive engagement with affected people.	Applicable. See **Error! Reference source not found. - Error! Reference source not found.**.
Institutional Arrangements & Capacity	Borrower/client must maintain sufficient implementation capacity.	Applicable. See Chapter 13.1 - ESHS Roles and Responsibilities.
Monitoring & ADB Supervision	ADB supervises, reviews compliance, and monitors safeguard implementation.	Applicable. See Chapter 14 - Environmental and Social Monitoring Programme.

In addition to applicable national requirements and ADB safeguard requirements, the Project shall be guided by relevant Good International Industry Practice (GIIP) for large hydropower development.

These standards and guidance documents shall be considered during detailed design, construction, commissioning, operation, maintenance, dam safety management, climate risk management, and environmental and social performance monitoring.

The following international standards and good practice guidance are applicable to the Project, as relevant:

- International Commission on Large Dams (ICOLD) bulletins and guidance on dam safety, design review, construction quality control, reservoir impoundment, operation, maintenance, surveillance, emergency preparedness, and dam safety risk management
- ADB Safeguard Policy Statement (2009) and applicable ADB environmental and social safeguard requirements for Category A projects
- ADB Energy Policy: Supporting Low-Carbon Transition in Asia and the Pacific (2021), including principles related to sustainable, low-carbon, climate-resilient energy development;
- ADB Approach for Large Hydropower Plants (2003), particularly in relation to technical due diligence, environmental and social risk management, dam safety, downstream impacts, and benefit-sharing considerations
- Hydropower Sustainability Guidelines on Good International Industry Practice (HGIIP), International Hydropower Association / Hydropower Sustainability Alliance (2018), including good practice expectations for environmental and social assessment, biodiversity, hydrological resources, climate change mitigation and resilience, infrastructure safety, project benefits, resettlement, stakeholder engagement, and cultural heritage
- IFC Environmental, Health and Safety Guidelines, including the General EHS Guidelines and relevant sector guidance applicable to construction, occupational health and safety, community health and safety, hazardous materials, waste management, noise, air emissions, and wastewater management
- World Bank Environmental and Social Framework good practice notes and dam safety guidance, where relevant to hydropower projects, emergency preparedness, community safety, and climate resilience
- International Labour Organization (ILO) conventions and good practice standards relevant to labor management, working conditions, occupational health and safety, child labor, forced labor, non-discrimination, and workers' grievance mechanisms and
- internationally recognized climate risk and resilience guidance, including climate and disaster risk screening, hydrological risk assessment, flood safety, GLOF/LDOF risk consideration, and adaptive management for infrastructure exposed to climate-related hazards.

The application of these GIIP references shall be proportionate to the nature, scale, and risk profile of the Project. Where national requirements and international good practice differ, the Project shall adopt the more stringent requirement, unless otherwise justified and agreed with the relevant authorities and lenders. These standards shall be reflected, as applicable, in the detailed design, dam safety arrangements, construction supervision, ESMP implementation, operation and maintenance procedures, emergency preparedness planning, and monitoring and reporting systems.

2.6 Gap Analysis

An analysis of the ADB Project-relevant requirements against the national legal framework is presented in Table 10

Table 9: Gap analysis between ADB's SPS (2009) and the Bhutanese national legal framework

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
Safeguard Requirements 1- Environmental Safeguard, 2002	▪ The Constitution of Kingdom of Bhutan, 2008 ▪ Alternate Renewable Energy Policy, 2013 ▪ Bhutan Sustainable Hydropower Development Policy, 2021 ▪ National Environment Protection Act 2007 ▪ Waste Prevention and Management Act of Bhutan, 2009 ▪ Guideline to Determine Minimum Environmental Flow Regulations for Dewatered Reaches of Hydropower Projects in Bhutan, 2019 ▪ Environmental Assessment Guideline for Hydropower 2012	▪ Scope/depth of alternatives analysis ▪ Requirements for cumulative impact assessment ▪ Specificity of ESMP content and adaptive management triggers. ▪ ADB's ESF requires adaptive management, where some safeguard measures can be implemented after project approval through Environmental and Social Commitment Plans (ESCPs). Bhutan's system generally requires upfront approval of EIAs and other permits before project commencement, with less flexibility for post-approval adjustments. ▪ Timelines and methods for public disclosure of ESIA documents ▪ Stringency of requirements for independent monitoring. ▪ Bhutan's law does not formally adopt the mitigation hierarchy or require proportional assessment based on risk levels, which are central to ESS	▪ The ESIA has been prepared in accordance with ADB SPS (2009) and informed by relevant GIIP and IFC PS6 principles. ▪ The Project includes Critical Habitat Screening, Critical Habitat Assessment (CHA), cumulative impact assessment, ecosystem services assessment, biodiversity management planning, environmental flow assessment, climate risk assessment, adaptive management framework, and detailed ESMPs.
Safeguard Requirements 2: Involuntary Resettlement, 1995	▪ Alternate Renewable Energy Policy, 2013 ▪ Bhutan Sustainable Hydropower Development Policy, 2021 ▪ The Land Act of Bhutan, 2007 ▪ Forest and Nature Conservation Act, 2023 ▪ Mines and Minerals Act of Bhutan, 1995 ▪ National Environmental Protection	The implementation of involuntary resettlement is closely linked with Institutional Arrangements, requiring the client (Government/SOE) to demonstrate sufficient Organizational Capacity and integrate the RP/RAP budget and activities into the overall project design, procurement, and contract management processes. The Bhutanese law differs from the ADB requirements in the following topics:	▪ A Project-specific Resettlement Plan (RP) has been prepared in accordance with ADB SPS 2009.

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
	▪ Act of Bhutan, 2007 ▪ The Local Government Act of Bhutan 2009 and amendment 2014 ▪ Land Acquisition and Compensation Rules and Regulations, 2022 ▪ Land Compensation Rates, 2022	▪ Definition of "project-affected persons" (APs), especially informal land users or those without formal title. ▪ Valuation methodologies for full replacement cost, as Bhutan Schedule of Rates (BSR) 2024 is taken as reference for valuation ▪ Emphasis and detailed planning for livelihood restoration beyond cash compensation. ▪ Specific measures for vulnerable groups within APs. ▪ Consultation processes specific to resettlement. ▪ Develop a Resettlement Plan following ADB standards, including grievance mechanism.	
Safeguard Requirements 3: Indigenous Peoples, 2007	▪ (No specific Bhutanese policies directly listed for ESS7 in the "Relevant Bhutan Policies" column, but cross-referencing to gaps suggests some relevance of policies mentioned elsewhere)	▪ Lack of legal categorization as 'indigenous peoples' under national law (see also Annex 9). ▪ Reliance on general conservation/heritage laws rather than specific IP rights frameworks. ▪ Non-ratification of ILO 169 / non-signatory to UNDRIP. ▪ In line with ADB SPS 2009 requirements, the Project will undertake meaningful consultation, information disclosure, and stakeholder engagement throughout the Project cycle. ▪ As the Indigenous Peoples safeguard is not triggered for the Project, Free, Prior, and Informed Consent (FPIC) requirements under ADB SPS 2009 are not applicable ▪ A loan agreement may potentially give rise to legal obligations for the borrower if certain legal arrangements are not adequately addressed or mitigated.	▪ Indigenous Peoples screening was undertaken in accordance with ADB SPS 2009 criteria. ▪ Accordingly, Safeguard Requirement 3 is not triggered for the Project and FPIC requirements are not applicable. ▪ Nevertheless, the Project will implement meaningful consultation, information disclosure, culturally respectful engagement, and accessible grievance management throughout the Project cycle.

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
Safeguard Requirements 4: Special Requirements for Different Finance Modalities	▪ Public Finance Act of Bhutan, 2007	▪ Outline of a Resettlement Framework, Outline of an Indigenous Peoples Planning Framework, ADB Prohibited Investment Activities List	▪ The Project has incorporated safeguard due diligence requirements consistent with ADB financing modalities, including preparation of ESIA, RP, Biodiversity Action Plan, Stakeholder Engagement Plan, Environmental and Social Monitoring Programme, and associated safeguard implementation frameworks.
ADB Prohibited Investment Activities List-5	▪ National Environmental Protection Act of Bhutan, 2007 ▪ Waste Prevention and Management Act of Bhutan, 2009 ▪ Forest and Nature Conservation Act, 2023	Do not qualify for Asian Development Bank financing: ▪ Activities involving harmful or exploitative forms of forced labor or child labor. ▪ Production of or trade in any product or activity deemed illegal under host country laws or regulations or international conventions and agreements, or subject to international phaseouts or bans, including: - Pharmaceuticals, pesticides, and herbicides - Ozone-depleting substances - Polychlorinated biphenyls (PCBs) and other hazardous chemicals - Wildlife or wildlife products regulated under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) - Transboundary trade in waste or waste products ▪ Production of or trade in weapons and munitions, including paramilitary materials. ▪ Production of or trade in alcoholic beverages, excluding beer and wine. ▪ Production of or trade in tobacco.	

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
		▪ Gambling, casinos, and equivalent enterprises. ▪ Production of or trade in radioactive materials, including nuclear reactors and components thereof. ▪ Production of, trade in, or use of unbonded asbestos fibers. ▪ Commercial logging operations or purchase of logging equipment for use in primary tropical moist forests or old-growth forests. Marine and coastal fishing practices that are harmful to vulnerable, threatened, or protected species, including large-scale pelagic drift net fishing and fine-mesh net fishing.	
Strengthening and Use of Country Safeguard Systems to Address Environmental and Social Safeguard Issues-6		ADB and Borrowers Responsibility ▪ Overall Approach to the Strengthening and Use of Country Safeguard Systems in ADB-Supported Operations	▪ Supplemental safeguard measures consistent with ADB SPS have been incorporated into the ESIA, RP, BMP, ESMP, Stakeholder Engagement Plan, GRM, and monitoring framework.

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
ADB Social Protection Strategy (2001)	▪ Labour And Employment Act of Bhutan, 2007 ▪ Regulations on Occupational Health, Safety and Welfare, 2022 ▪ Regulations on Working Conditions, 2022 ▪ Regulation on Foreign Workers Management, 2024	▪ Social protection interventions (labor markets, social insurance, social assistance, micro and area-based schemes, child protection) Missing in the Bhutanese law are: ▪ Explicit incorporation/ enforcement of all ILO Core Labor Standards (esp. freedom of association, collective bargaining) ▪ Specificity of OHS requirements (e.g., vs. WBG EHS general/ industry guidelines) ▪ Standards for worker accommodation and site conditions ▪ Effectiveness and accessibility of worker-specific GRMs ▪ Adoption and implementation of labor management plans (LMP) compliant with ADB standards	▪ Project includes ESMP, Occupational Health and Safety Plan, Workers Code of Conduct, worker GRM, occupational health and safety monitoring consistent with ADB safeguard expectations and GIIP.
ADB Gender and Development Policy (1998)	▪ National Gender Equality Policy (NGEP), 2020 ▪ Climate Change Policy, 2020	▪ Adoption of gender mainstreaming in all ADB operations rather than treating women-only projects separately. ▪ Emphasis on gender sensitivity, analysis, planning, and agenda setting across programs ▪ Operational approaches to ensure gender issues are considered at each stage of the project cycle	▪ Gender-responsive stakeholder consultations, gender-disaggregated baseline analysis, livelihood restoration support, women's participation measures, SEAH risk mitigation measures, have been incorporated into the ESIA, RP, Stakeholder Engagement Plan, and GVAAP.
ADB Access to Information Policy (2018)	▪ Constitution of the Kingdom of Bhutan, 2008 ▪ National Environment Protection Act 2007 ▪ Local Government Act of Bhutan, 2009 ▪ Environmental Assessment Act, 2000	▪ Prescriptiveness on how meaningful consultation is defined and achieved (e.g., two-way dialogue, incorporation of feedback). ▪ Accessibility of information for diverse stakeholder groups (language, literacy, location). ▪ Proactive vs. reactive disclosure.	▪ Project includes a Stakeholder Engagement Plan (SEP), public consultation programme, ongoing stakeholder engagement mechanisms, information disclosure procedures, project-level grievance redress mechanism, disclosure of ESIA/RP documents

ADB SPS (2009)	Relevant Bhutan policy and legal framework	Potential areas where Bhutanese regulations might differ / have gaps with the ADB's ESSSPS	Project-Specific Gap-Filling Measures Adopted for Bunakha HPP
	▪ The Local Government Act of Bhutan 2009 and amendment 2014	▪ Independence and effectiveness of project-level GRMs. Establish Stakeholder Engagement Plan (SEP)	

2.7 Permits and Approvals

2.7.1 Approval of the ESIA report by NEC

Environmental clearance for development projects in Bhutan is governed by the Regulation for the Environmental Clearance of Projects (2016), established under the Environmental Assessment Act (2000). This regulation provides a comprehensive framework for assessing and approving projects, ensuring they are consistent with Bhutan's environmental policies and sustainable development objectives. It guides DGPC in integrating environmental considerations into planning and implementation stages.

The National Environment Commission (NEC) serves as the primary authority responsible for enforcing this Regulation. The environmental clearance process involves several key steps such as initial screening to determine whether a project requires an environmental assessment, public consultation to engage stakeholders and gather input on potential environmental impacts, a detailed environmental assessment to evaluate the project's effects on the environment and finally, the issuance of environmental clearance for projects that meet prescribed environmental standards.

The statutory clearance processes and requirements including environmental and social obligations are necessary steps for proceeding with the implementation of the Bunakha HPP Project, as shown in Figure 1.

Source: Consultant, based on the Environmental Assessment Act, 2000 and the Regulation for the Environmental Clearance of Projects, 2016.

Figure 1: The environmental clearance process in Bhutan

2.7.2 Process as per this ESIA and this Project

As the Project falls under the "Red Category", the EC application will be reviewed by the Department of Environment and Climate Change (DECC, erstwhile NECS).

The TOR of the Project was submitted by DGPC to DECC on January 22nd 2025. Following the review, DECC endorsed the TOR on February 10th 2025 with a validity of 2 years. After submission of the EIA to DECC, the time frame of the review process will be negotiated between DECC and DGPC. If any additional information is requested during the review period, it must be submitted within 1 year. On approval of the clearance, a legal undertaking with DGPC will be signed for compliance with the EA Act, 2000.

Table 10: Clearance Table and Timeline

Approval / Clearance	***Responsible Authority***	***Current Status***	***Date / Timeline***
Submission of Terms of Reference (ToR)	DGPC to DECC	Completed	22 January 2025
Approval of ToR	DECC	Approved	10 February 2025 (Valid for 2 years)
Submission of EIA Report	DGPC to DECC	In Progress	
Technical Review of EIA	DECC	Pending	Timeline to be agreed between DECC and DGPC following EIA submission
Submission of Additional Information (if requested)	DGPC	As required	Within 1 year of DECC request
Environmental Clearance (EC) Approval	DECC	Pending	Following satisfactory completion of the EIA review
Signing of Legal Undertaking	DGPC and DECC	Pending	After issuance of Environmental Clearance

2.7.3 Procurement, agreements, and ESS integration

Under international best practices, the contractual terms of a loan agreement are legally binding on the government, requiring all parties to adhere to the agreed conditions throughout the project lifecycle. In many cases, the procurement and social safeguard requirements of funding agencies take precedence over national procurement laws, which can occasionally lead to conflicts or inconsistencies.

To ensure compliance, bid and contract documents must incorporate environmental and social safeguard (EES) provisions. These include explicit references to obligations outlined in the Environmental and Social Impact Assessment (ESIA) and Environmental and Social Management Plan (ESMP), as well as measures related to grievance redress mechanisms (GRM), labor standards, resettlement, indigenous peoples, and other relevant safeguard elements.

2.8 Environmental Quality and Emission Standards Applicable to the Project

The primary and legally binding regulatory benchmark for this Project is Bhutan's Environmental Standards 2020 (ES 2020), issued by the National Environment Commission (NEC). These standards define the permissible limits for pollutant discharges and ambient environmental quality within the Kingdom. All Project activities, from construction through operation, must adhere to these standards to obtain and maintain the required Environmental Clearance.

To provide a global best-practice context and align with the requirements of the ADB, this report also references the latest health-based guidelines from the World Health Organization (WHO). These guidelines are often more stringent than national standards as they are based solely on the latest scientific evidence regarding health impacts, without consideration for economic or technical feasibility. The key international benchmarks used are:

- WHO Global Air Quality Guidelines (AQG) 2021: These guidelines provide recommendations on air quality levels necessary to protect public health from the adverse effects of air pollution.
- WHO Environmental Noise Guidelines for the European Region (2018): Although region-specific, these are widely used globally as a benchmark for assessing the health impacts of environmental noise.
- WHO Guidelines for Drinking-water Quality (GDWQ): These provide the authoritative basis for setting national regulations and standards for water safety to protect public health from chemical and microbial contaminants.
- Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the Protection of Environmental and Human Health: These are widely recognized as Good International Industry Practice (GIIP) for assessing potential risks from soil contamination, particularly when comprehensive national standards are not available.

2.8.1 Applicable standards for air quality

For the purposes of this assessment, the Project's Area of Influence is classified as a "Mixed Area" under ES 2020. The key applicable national limits and the corresponding international health-based guidelines are summarized in Table 11.

Table 11: Key Regulatory Standards and Guidelines for Air Quality applicable to the Bunakha HPP

Parameter	Averaging Period	Bhutan ES 2020 Limit (Mixed Area)[1]	WHO Guidelines[2]
Air Quality			
TSPM	24-hour mean	60 µg/m³	-
Particulate Matter ($PM_{2.5}$)	24-hour mean	60 µg/m³	5 µg/m³
Particulate Matter (PM_{10})	24-hour mean	200 µg/m³	10 µg/m³
Nitrogen Dioxide (NO_2)	24-hour mean	120 µg/m³	25 µg/m³
Sulphur Dioxide (SO_2)	24-hour mean	120 µg/m³	40 µg/m³
Ozone (O_3)	8-hour mean (peak season)	100 µg/m³	60 µg/m³

Parameter	Averaging Period	Bhutan ES 2020 Limit (Mixed Area)[1]	WHO Guidelines[2]
Carbon Monoxide (CO)	8-hour mean	4 mg/m³	10 mg/m³

[1] Source: Environmental Standards 2020, National Environment Commission, Royal Government of Bhutan.
[2] Source: WHO Global Air Quality Guidelines (AQG) 2021.

2.8.2 Applicable standards for noise

The key applicable national standards (community protection) and international guidelines (community and occupational protection) for environmental noise are (Table 12):

- Environmental Standards (ES 2020): These national standards set legally binding limits for noise in community areas to prevent annoyance and sleep disturbance. For a "Mixed Area," the limits are 65 dBA (Daytime, Leq) and 55 dBA (Night-time, Leq). These apply to the Project's impact on sensitive receptors.
- WHO Environmental Noise Guidelines for the European Region (2018): These health-based guidelines provide recommendations to protect against the adverse health effects of road traffic noise. The recommendations are to maintain levels below 53 dBA (Lden) for average exposure and below 45 dBA (Lnight) for night-time exposure. These are used as an international benchmark.
- Occupational Health Standards (WHO, 2018): These standards protect workers from hearing damage. The WHO recommends limiting worker exposure to a maximum of 85 dBA as an 8-hour Time-Weighted Average (TWA). This applies to Project personnel in work zones.

Table 12: Key Regulatory Standards and Guidelines for Noise applicable to the Bunakha HPP

Parameter	Averaging Period	Bhutan ES 2020 Limit (Mixed Area)[1]	WHO Guideline
Noise			
Ambient Noise Level	Daytime (06:00-22:00)	65 dBA (Leq)	**< 53 dBA (Lden)[2]** (for road traffic)
Ambient Noise Level	Night-time (22:00-06:00)	55 dBA (Leq)	**< 45 dBA (Lnight)[2]** (for road traffic)

[1] Source: Environmental Standards 2020, National Environment Commission, Royal Government of Bhutan.
[2] Source: WHO Environmental Noise Guidelines for the European Region (2018). These are strong recommendations to prevent adverse health effects from road traffic noise. Lden is the day-evening-night average sound level, and Lnight is the night-time average.

2.8.3 Applicable standards for water quality

The assessment of water quality utilizes a use-based classification system as defined in Bhutan's ES 2020. The standards applied vary depending on the nature of the sampled water source:

- River water quality: Samples collected from the Wangchhu River and its major tributaries are assessed against the Standards for River Water Quality of ES 2020. These standards classify water bodies based on their designated best uses, such as fisheries, irrigation, and aquatic life propagation.

- Drinking water quality: Samples from community springs that serve as primary drinking water sources are evaluated against the much stricter Standards for Drinking Water Quality of ES 2020. For international best-practice comparison, the WHO Guidelines for Drinking-water Quality are also referenced.
- Effluent discharge: While not part of the baseline, any future wastewater discharges from Project camps or facilities will be required to comply with the Standards for Industrial Effluent Discharge as per ES 2020. The compliance with these standards is not evaluated in this report.

Due to the extensive list of parameters for each standard, the specific limit values are presented directly within the water quality analysis chapter (Chapter 7.1.7) for direct comparison with the analytical results.

2.8.4 Applicable standards for soil quality

Unlike the specific numerical limits provided for air, noise and water, Bhutan's Environmental Standards (ES 2020) contain general, qualitative requirements for land management but do not provide a comprehensive set of numerical standards for ambient soil quality (e.g., maximum permissible concentrations for heavy metals or hydrocarbons).

In such cases where specific national standards are not available, the Asian Development Bank's SPS requires the application of Good International Industry Practice (GIIP). This involves referencing internationally recognized, health-based standards to provide context for the baseline data.

In accordance with GIIP, the results for specific potential contaminants (e.g., heavy metals, hydrocarbons) are screened against the Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the Protection of Environmental and Human Health for Residential/Parkland use (Table 13). These guidelines are a widely accepted international benchmark for assessing potential health risks.

This screening approach serves two key purposes:

1. It helps to identify any pre-existing areas of potential concern that may require management, regardless of the Project.
2. It confirms the current suitability of the soil in the Project areas for its intended future uses, establishing a clear, defensible pre-Project condition.

Table 13: Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the Protection of Environmental and Human Health for Residential/Parkland use

Sl. No.	Test Parameter	Unit	CCME Guideline (Residential/ Parkland)
1	Texture	-	-
2	Moisture Content	%	-
3	Alkalinity (as $CaCO_3$)	mg/kg	-
4	Acidity (as $CaCO_3$)	mg/kg	-
5	Porosity	%	-
6	pH at 25°C	-	-
7	Electrical Conductivity at 25 °C	mS/cm	-
8	Nitrogen (as N)	mg/kg	-

9	Phosphate (as P)	mg/kg	-
10	Potassium (as K)	mg/kg	-
11	NPK	Ratio	-
12	Calcium (as Ca)	mg/kg	-
13	Magnesium (as Mg)	mg/kg	-
14	Chloride(as Cl)	mg/kg	-
15	Sulphate (as SO_4)	mg/kg	-
16	Carbonate	mg/kg	-
17	Boron (as B)	mg/kg	-
18	Sodium (as Na)	mg/kg	-
19	Cation Exchange Capacity	meq/100gm	-
20	Arsenic (as As)	mg/kg	12
21	Cadmium (as Cd)	mg/kg	1.4
22	Mercury (as Hg)	mg/kg	6.6
23	Nickel (as Ni)	mg/kg	50
24	Manganese (as Mn)	mg/kg	1900
25	Hexavalent Chromium (as Cr^{+6})	mg/kg	0.8
26	Lead (as Pb)	mg/kg	70
27	Iron (as Fe)	mg/kg	-
28	Copper (as Cu)	mg/kg	63
29	Zinc (as Zn)	mg/kg	200
30	Sodium Adsorption Ratio(SAR)	-	500
31	Organic Carbon	%	64
32	Organic Matter	%	50
33	Water Holding capacity	%	5
34	Barium (as Ba)	mg/kg	1.6
35	Total Chromium(as Cr)	mg/kg	12
36	Cobalt (as Co)	mg/kg	1.4
37	Molybdenum (as Mo)	mg/kg	6.6
38	Cyanide (as CN)	mg/kg	50

3 Project Description

The Bunakha HPP is planned to be located at latitude 27º08’00’’N and longitude 89º32’33’’E near Bunakha and Geling Gewogs, Chhukha Dzongkhag, on the river Wangchhu, Bhutan (Figure 2). This river is formed by the confluence of three major snow-fed streams viz. Paro Chu, Thimphu Chu and Ha Chu, originating in the Jumolhari glaciers in the Himalayas. The Project site lies approximately 3.25 km upstream of the existing Chhukha Dam.

Figure 2: Location of the Bunakha HPP within Bhutan (the red polygon represents the Project’s Area of Influence - see Chapter 4)

The Bunakha HPP is being developed by the Royal Government of Bhutan under direct oversight of DGPC (Druk Green Power Corporation), reachable at:

- Post Box 1351, Thori Lam, Thimphu 11001
- +975 2 336414
- dgpc.info@drukgreen.bt

The environmental focus person at DGPC is Ms. Kinzang Dolma, Assistant Environmental Officer, reachable at:

- Email: k.dolma3853@drukgreen.bt
- Mobile: +975 77330839
- Post Box 1351, Thori Lam, Thimphu 11001
- +975 2 336414

3.1 Access

The Project site is accessible via the Phuentsholing–Thimphu Primary National Highway, which also forms part of the Asian Highway Network. Phuentsholing, a major town on the Indo-Bhutan border, is located approximately 94 km from the Bunakha Project site and about 180 km from Siliguri, a key urban center in West Bengal, India. The highway is classified as Class 70R in accordance with Indian Roads Congress (IRC) standards, and the bridges along the route are designed to accommodate loads of up to 70 metric tons (MT). As a Primary National Highway, no geometric improvements or structural strengthening of the existing highway and bridges are required up to the junction with the Chanachen Farm Road. Consequently, the route is well suited for Project implementation and will serve as the primary transportation corridor during construction.

The Project will primarily utilize the existing transportation infrastructure, including the Phuentsholing–Thimphu Highway and local access roads. Limited improvement works will be undertaken on sections of the existing Chanachen Farm Road to facilitate the transportation of construction materials, equipment, and personnel. In addition, the existing bridge providing access to the Chanachen Farm Road will be upgraded or replaced to safely accommodate Project-related traffic and loading requirements. These works will largely be confined to the existing road corridor, thereby minimizing the need for new road construction. Potential environmental and social impacts associated with the access improvements, including temporary land use requirements, construction-related disturbances, traffic impacts, community safety considerations, and any associated land acquisition or livelihood impacts, have been assessed as part of the Project and are addressed through the ESIA and Resettlement Plan, where applicable. Further details of the bridge replacement are provided in Replacement of the bridge at the Chanachen farm road Section 3.4.12.

Paro International Airport, the country's only international airport, is located approximately 50 km from the Project site. The nearest railway facilities are located in India. Hasimara Railway Station in West Bengal is approximately 112 km from the Project site, while New Alipurduar Station, situated on the New Jalpaiguri–Guwahati Broad Gauge line of the Northeast Frontier Railway, is approximately 70 km from Phuentsholing. Facilities for unloading, storage, and handling of heavy equipment and machinery are available at Falakata in West Bengal, approximately 60 km from Phuentsholing and about 154 km from the Project site by road.

The nearest seaport is Kolkata Port in West Bengal, India, located approximately 814 km from the Project site by road. Access from the highway to the riverbed at the Project site requires a descent of approximately 180 m, which typically takes about one hour on foot.

3.2 Type of Project

Bunakha HPP is the uppermost major project in the development of the power potential of the Wangchhu River. It is a storage project utilizing the head upstream of the existing Chhukha HPP. It will also enhance the power generation in the existing downstream Chhukha and Tala HPPs, as well as in the proposed Wangchhu HPP. The Project envisages construction of a 205 m high RCC (Roller Compacted Concrete) dam with an installed capacity of 180 MW (3 X 60 MW) - further key characteristics are shown in Box 1.

Box 1: Key characteristics of the Bunakha HPP

Location:

- Country: Bhutan
- River: Wangchhu
- Dam Site: Near Bunakha village (3.25 km u/s of Chhukha HPP)
- Latitude: 27°08'00''N
- Longitude: 89°32'33''E
- Nearest airport: Paro (50 km)

Reservoir:

- Maximum Water level (MWL): EL 2,008 m
- Full Reservoir Level (FRL): EL 2,006 m
- Min. Drawdown Level (MDDL): EL 1,950 m
- Gross Storage: 240.53 Mcum
- Live Storage: 157.90 Mcum
- Net head: 143 m (approximately)
- Area under submergence at FRL: 4.25 km^2
- Length of the reservoir: 17.25 km at FRL

Source: DPR Update, Feb. 2026

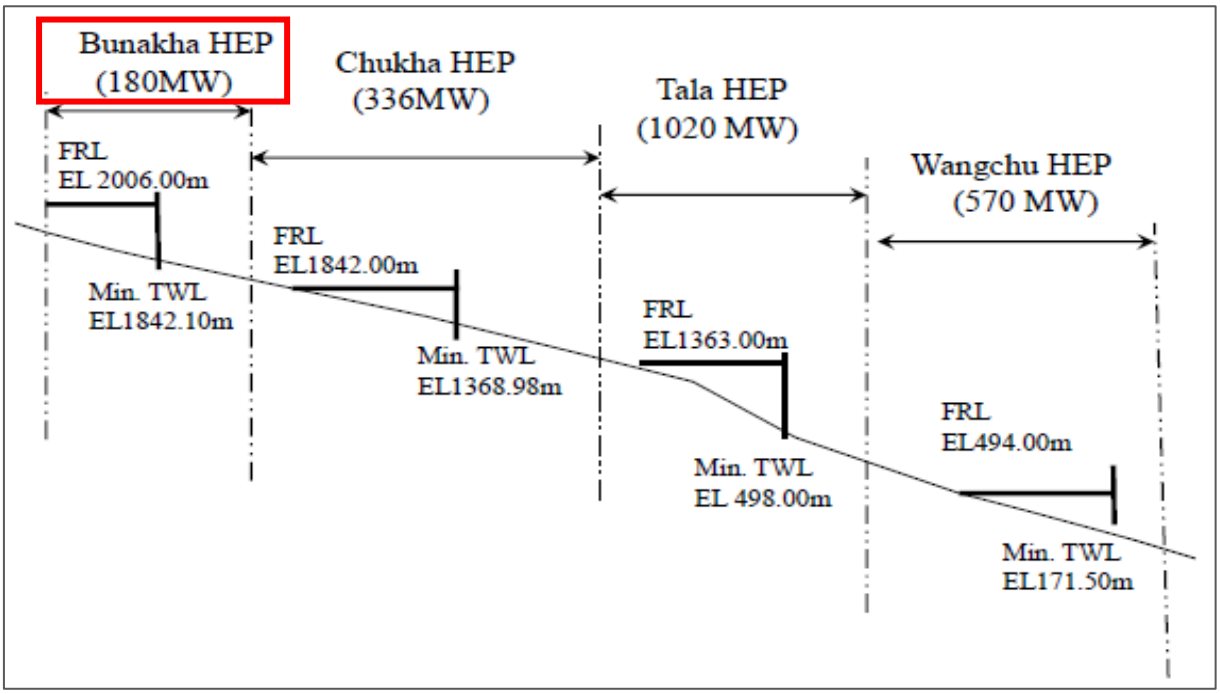
The Project is expected to achieve an annual energy generation of 746 GWh in the 90% dependable year at the Bunakha site alone. It will also generate an additional annual energy of 186 GWh at Chukha, 329 GWh at Tala and 120 GWh at Wangchhu. The operation of the Bunakha HPP will benefit an additional total annual energy generation of 632 GWh for the 90% dependable year.

3.3 Hydropower projects within the Wangchhu River Basin

The Wangchhu basin currently hosts two major hydropower plants: the Chhukha Hydropower Plant (CHP or Chhukha HPP), with an installed capacity of 336 MW, and the Tala Hydropower Plant (THP or Tala HPP), with an installed capacity of 1,020 MW. The THP's dam is located immediately downstream of the tailrace tunnel of the CHP.

Two additional HPPs are planned in the Wangchhu basin: the Wangchhu Hydropower Project (WHPP) and the BHPP, for which the Detailed Project Reports (DPRs) are currently being updated. The WHP is proposed further downstream of the THP and includes two DPR options—one based on a run-of-river scheme and the other on a reservoir scheme.

The cascade of the upstream/downstream projects indicating the approved levels (FRL - Full Reservoir Level and TWL - tailwater level) is shown in Figure 3.



Source: DPR, 2005

Figure 3: Cascade of Projects on river Wangchhu

The Bunakha HPP, which is the subject of the current study, is located approximately 3.2 km upstream of the CHP dam. Being the most upstream of all the projects in the basin, the reservoir scheme of the Bunakha HPP is expected to provide significant regulatory and operational benefits to all downstream hydropower developments.

3.3.1 Catchment Area Characteristics

Catchment Area	3,541 km^2
Mean Annual Runoff	2,996 Mcum
Probable Maximum Flood	9,224 M^3/s
Sedimentation Rate	6.68 MT/year

The catchment area up to the dam site is generally mountainous and covered with forests with elevations ranging from about 7,000 m to about 1,886 m.

As per the DPR prepared in 1995 by WAPCOS, the catchment area of the basin up to the proposed dam site is 3,714 km^2. On the basis of physiographic studies done by National Institute of Hydrology, Roorkee and reviewed again by the Consultant, the catchment area up to proposed Bunakha dam site has been revised to 3,541 km^2, out of which 34 km^2 is above 5,000 m elevation (less than 1% of total catchment area), considered as area above permanent snowline. Therefore, the whole catchment has been assumed as rain fed for hydrological analysis.

3.4 Engineering Characteristics

The key engineering characteristics of relevance for the ESIA are summarized below. Details can be consulted in the 2026 version of the DPR. The principal civil project components comprise:

- RCC main dam with crest level at EL. 2,010.0 m and four (4) gated spillway openings 22 m(H) by 16 m(W) with sill level at el. 1,986 m
- two mid-level outlets of size 6 m (H) by 4.5 m (W) at invert level of 1,915 m
- a side intake just upstream of the dam body on the left bank
- around 248 m long and 7.5 m diameter (finished) head race tunnel; 75 m deep 6.10 m diameter (finished) pressure shaft; and 72 m long 6.10 m (finished) diameter high pressure tunnel
- three circular penstocks of 3.5 m diameter underground powerhouse with three (3) 60 MW, vertical Francis turbines and generators
- main access tunnel to the powerhouse of 7.5 m diameter and 330 m length with invert at 1,873 m
- tailrace tunnel having a finished diameter of 7.5 m and length of 250 m

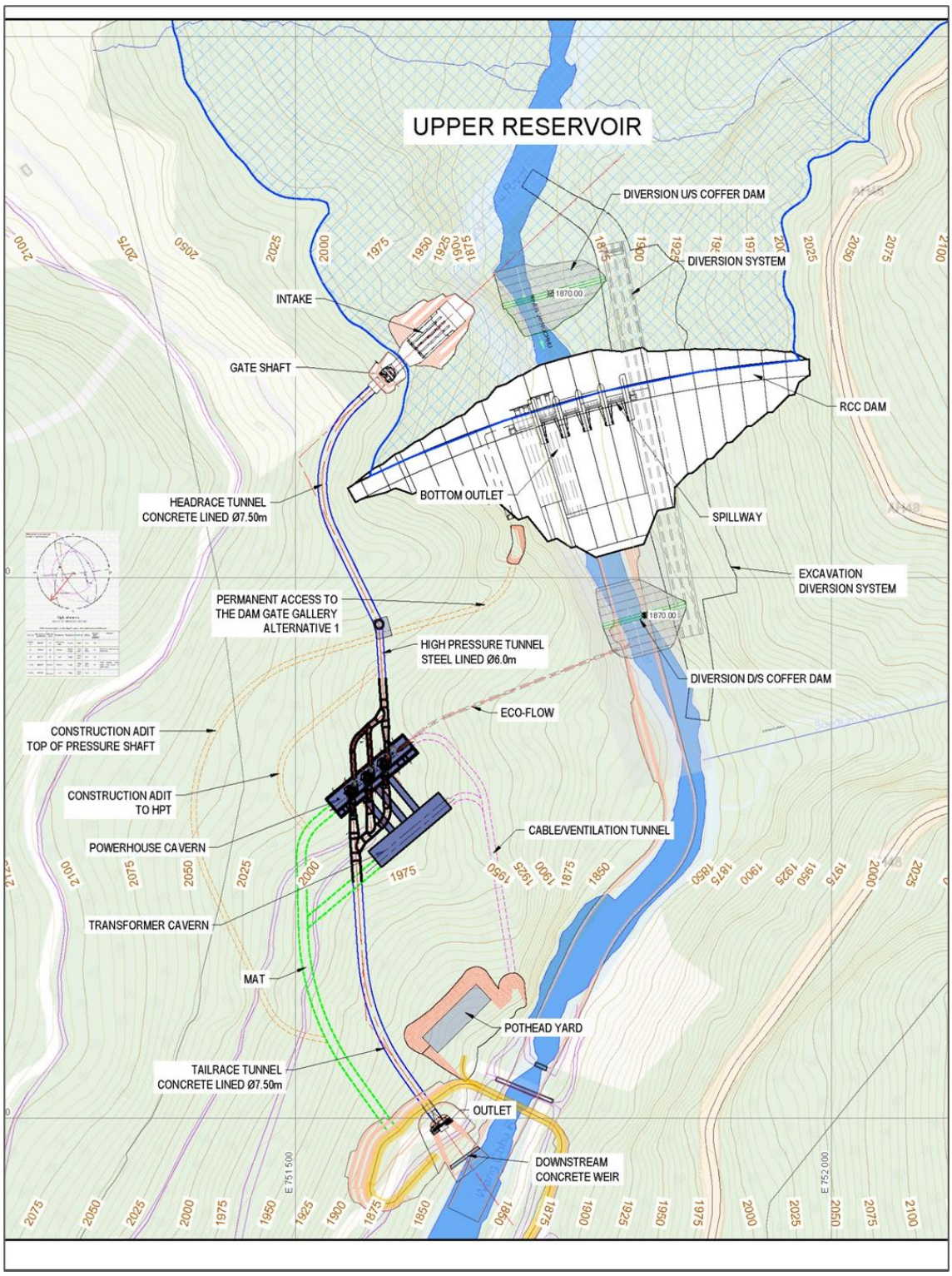


Figure 4: General Layout of Bunakha HPP

3.4.1 Dam

Type	Roller Compacted Concrete (RCC)
Top Width	15 m
Top Elevation of Dam	EL 2,010.0 m
Deepest Foundation Level	EL 1,805.0 m

Height of Dam above deepest Foundation Level	205 m
Length of Dam at the top	450 m

The Bunakha dam is classified as “large” under the 2024 Hydropower Guidelines of Bhutan and the International Commission on Large Dams (ICOLD) due to its gross storage capacity of 329.16 million m^3 and the 193 m upstream head above the lowest dam foundation level. This is a storage project planned to enhance power generation in the existing downstream Chhukha and Tala HPPs, as well as in the proposed Wangchhu HPP.

The Project envisages construction of a 205 m high RCC (Roller Compacted Concrete) dam, except the relevant structural members to be built with reinforced concrete. The dam will have an installed capacity of 180 MW (3 X 60 MW).The dam axis as approximately 65 m upstream (at mid-section) of the dam designed by THDC (DPR, 2013). The proposed layout is schematically represented in Figure 5.

The dam is of roller compacted concrete type and 205 m height from the lowest foundation level at 1,805 masl. Its crest is 450 m long at 2,010 masl. The dam is divided into 20 blocks, which includes 4 blocks for the gated spillway mid-section, 1 block for the mid-level outlets, and rest for non-overflow section. The block widths (perpendicular with flow direction) is 21.80 m.

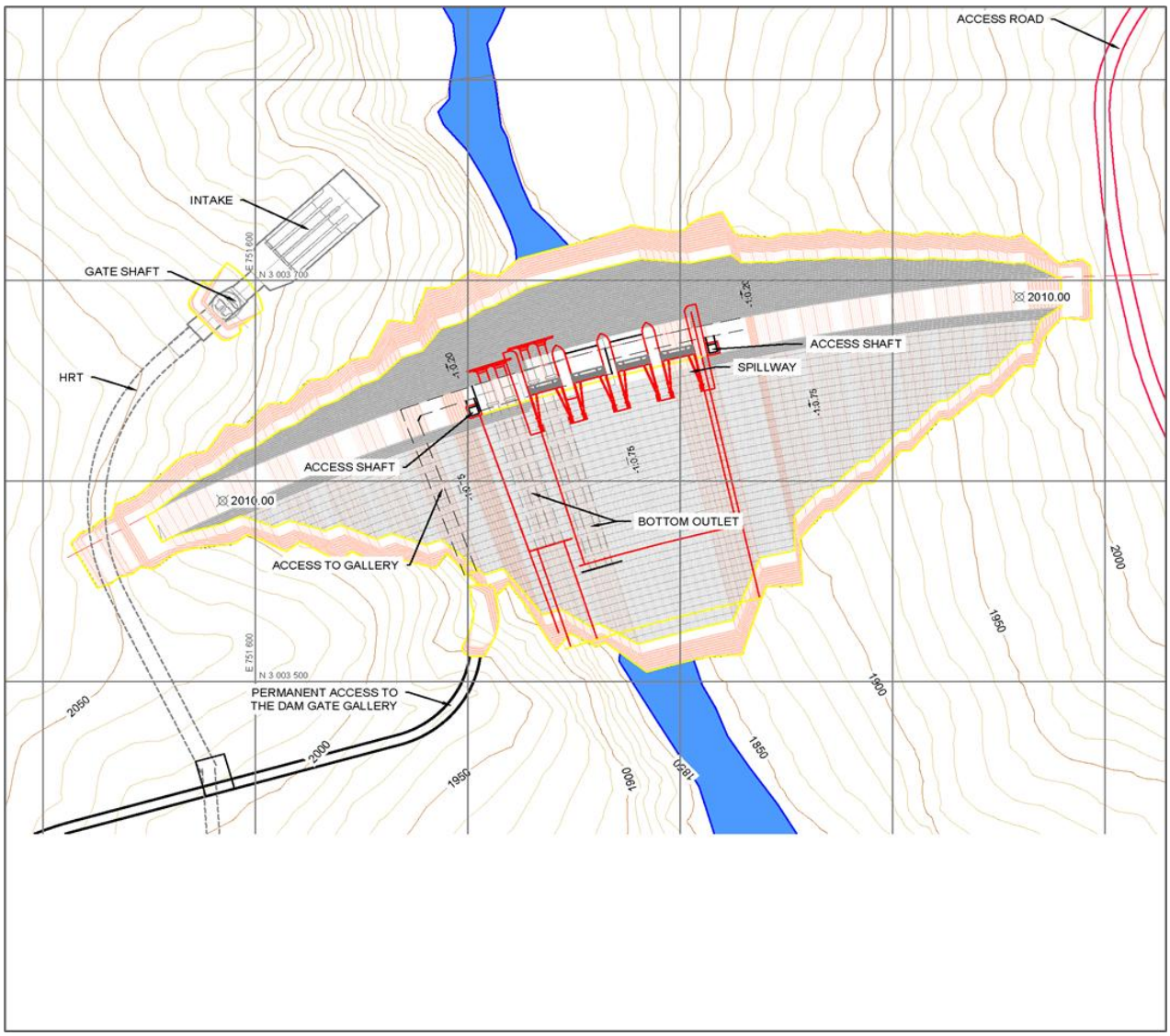


Figure 5: The proposed Bunakha HPP's dam layout

3.4.2 Mid-level Outlet

Number of Bays	2
Size of Bays	4.5 m wide by 6.30 m high (start) and 4.5 m wide by 6.0 m high (end)
Invert Level	EL 1,915.00 m

A mid-level outlet is incorporated in the dam as an independent structure primarily for long-term sediment flushing and rapid reservoir drawdown. It provides operational redundancy in case the bottom outlet becomes inoperable or insufficient, thereby ensuring continued sediment management under both normal and adverse conditions.

3.4.3 Bottom outlet

Number of Openings	2
Size of Bays	3.5 m (W) x 4.5 m (H)

Crest Level	EL 1,873.0 m

For the proposed large dam project, a bottom outlet is considered an essential safety and operational component in accordance with international dam engineering practice and ICOLD recommendations. The bottom outlet will serve multiple critical functions, including controlled reservoir filling and drawdown, release of environmental flows, sediment flushing, and emergency lowering of the reservoir during unsafe conditions.

3.4.4 Waterways (Head Race)

Type / number	**Headrace tunnel** / 1 Nos.
Lining	Concrete lined
Hydraulic diameter	Ø7.50 m, circular
Length / inclination	248 m / -10%
Type / number	**Pressure shaft** / 1 Nos.
Lining	Concrete lined (upper bend); steel lined (shaft section and lower bend)
Hydraulic diameter	Ø7.50 m (in concrete lining); Ø6.00 m (in steel lining)
Height / inclination	75 m / vertical
Type / number	**High pressure tunnel** / 1 Nos.
Lining	Steel lined
Hydraulic diameter	Ø6.00 m
Length / inclination	72 m / -10%
Type / number	**Distribution tunnel** / 1 Nos.
Lining	Steel lined
Hydraulic diameter	Ø4.25 m
Length / inclination	20 m / -1%
Type / number	**Upstream Manifold** / 3 Nos.
Lining	Steel lined
Hydraulic diameter	Ø3.00 m
Length / inclination	31 m (U1); 31 m (U2); 49 m (U3) / -1%

The water conveyance system consists of a single concrete-lined headrace tunnel with a circular finished diameter of 7.5 m and a length of approximately 248 m, which conveys water from the intake to the downstream pressure conveyance system. The headrace tunnel is connected to a vertical pressure shaft, having a diameter of 7.5 m in the concrete-lined section and 6.0 m in the steel-lined section, with a total height of about 75 m. Downstream of the shaft, a steel-lined high-pressure tunnel of 6.0 m diameter and 72 m length conveys flow towards the powerhouse. The system further includes a steel-lined distribution tunnel of 4.25 m diameter and approximately 20

m length, which distributes flow to the generating units. Three steel-lined upstream manifolds, each with a diameter of 3.0 m and lengths ranging from 31 m to 49 m, are provided to deliver water efficiently to the individual turbine units. The dimensions of these structures have been selected to safely convey the design discharge while maintaining the required hydraulic performance of the project.

3.4.5 Powerhouse and Transformer Cavern

Type	Underground
Design Discharge	46.00 m³/s
Rated Head	143.00 m (net)
Cavern Size	P Powerhouse cavern - 23.30 m (W) x 51.00 m (H) x 90.00 m (L) Transformer cavern – 19.10 m (W) x 27.85 m (H) x 85.00 m (L) Connecting tunnel – 40 m (L)
Type of Turbine and no. of units	Vertical Francis, 3 units of 60 MW each
Installed Capacity	180 MW

An underground powerhouse complex is proposed downstream of the right dam abutment. The complex consists of a powerhouse cavern, a transformer cavern connected by a 40 m long connecting tunnel from powerhouse cavern, and associated busduct galleries. The powerhouse cavern is designed with dimensions of 23.3 m in width, 51.0 m in height, and 90.0 m in length to accommodate the generating units and associated electro-mechanical equipment required for project operation.

The powerhouse is designed for an installed capacity of 180 MW, comprising three vertical Francis turbine-generator units of 60 MW each. The units will operate under a rated net head of 138.0 m with a rated discharge of 48.1 m³/s per unit. The powerhouse cavern includes dedicated service, unit, and unloading bays, along with multiple operating floors for turbines, generators, electrical systems, control facilities, and crane operation.

A transformer cavern is proposed adjacent to the powerhouse cavern and is connected through busduct galleries for power transmission. The transformer cavern, measuring 19.1 m in width, 27.85 m in height, and 85.0 m in length, will house three unit step-up transformers and a GIS installation. The cavern includes transformer bays, service areas, unloading facilities, and crane operating space to support safe and efficient operation and maintenance of the power evacuation system.

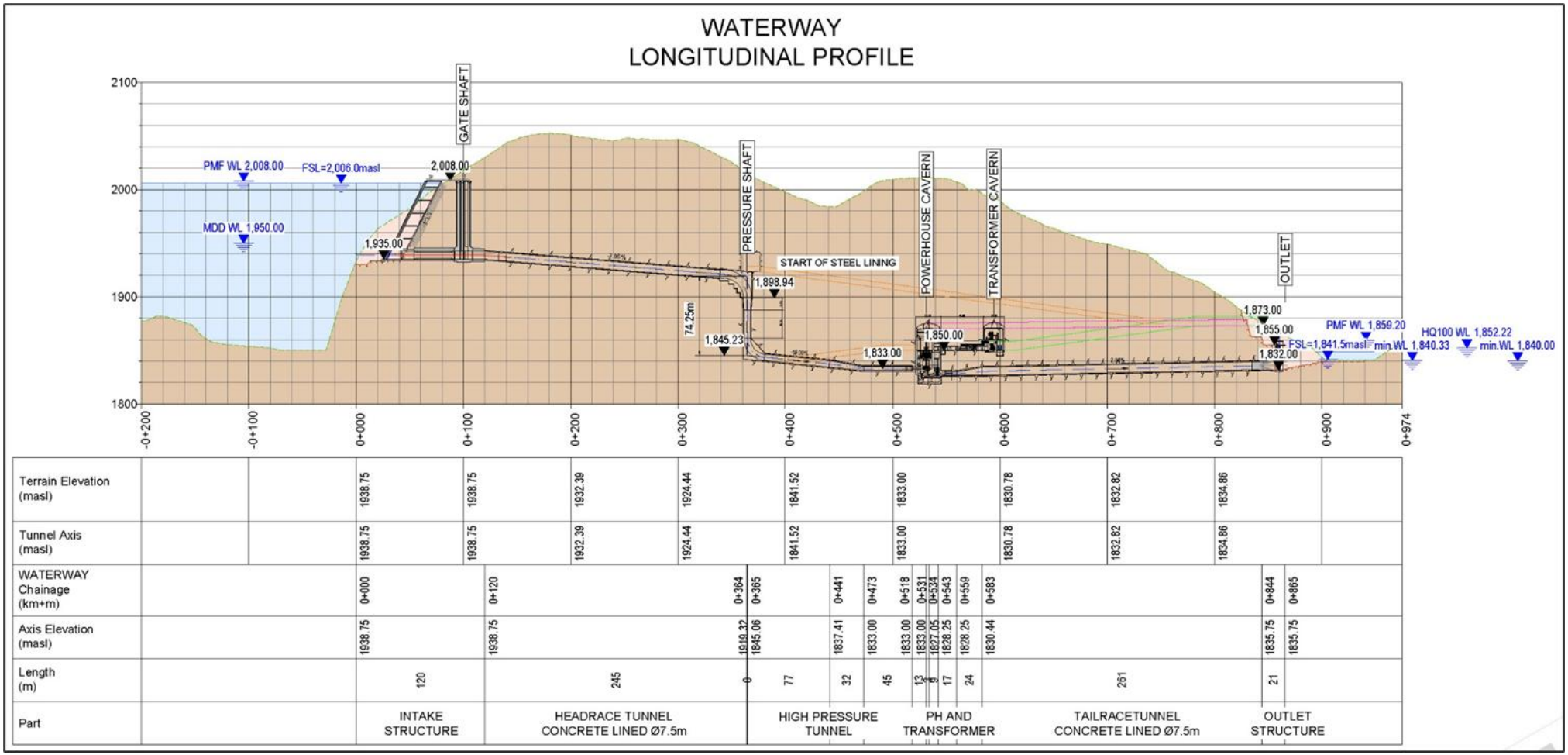


Figure 6: Longitudinal profile of waterway

3.4.6 Tailrace Conduit

Type / Number	**Downstream Manifold / 3 Nos.**
Lining	Concrete lined
Hydraulic Diameter	Ø4.00 m
Length / Inclination	54 m (U1); 36 m (U2); 36 m (U3) / 1%
Type / Number	**Collecting Tunnel / 1 Nos.**
Lining	Concrete lined
Hydraulic Diameter	Ø6.00 m
Length / Inclination	20 m / 1%
Type / Number	**Tailrace tunnel / 1 Nos.**
Lining	Concrete lined
Hydraulic Diameter	Ø7.50 m
Length / Inclination	250 m / 2%

The tailrace system consists of three downstream manifolds, a collecting tunnel, and a single tailrace tunnel. The downstream manifolds and collecting tunnel combine the discharge from the three generating units and convey it to the tailrace tunnel. The concrete-lined tailrace tunnel has a hydraulic diameter of 7.5 m and an approximate length of 250 m. It will safely discharge water from the underground powerhouse back to the river downstream. The tunnel dimensions have been selected to meet the project's hydraulic and operational requirements.

3.4.7 Tailrace outlet

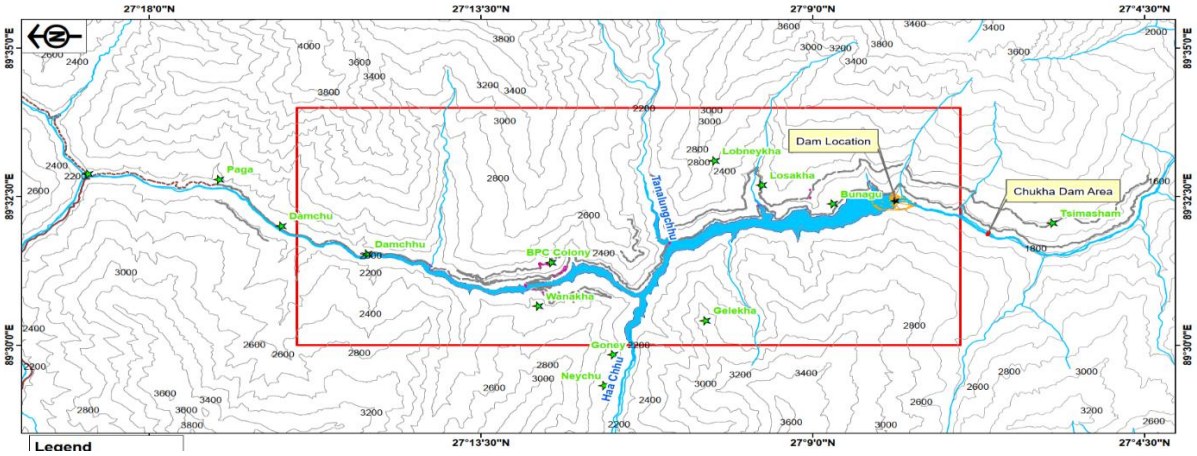
Type / number	Horizontal outlet with surface gate shaft / 1 Nos.
Levels	El. 1,832.00 m at invert / El. 1,855.00 m at operating platform
Hydraulic sizing	Ø7.50 m at start of transition; 5.90 m (W) x 7.50 m (H) at end of transition / gate shaft
Gate shaft height	15.50 m

A horizontal outlet with a surface gate shaft is proposed as part of the project. The outlet is located at EL 1,832.00 m at the invert level and is operated from a platform at EL 1,855.00 m. The structure transitions from a circular section of 7.5 m diameter to a gate shaft section measuring 5.9 m wide and 7.5 m high. The gate shaft has an approximate height of 15.5 m and will facilitate controlled reservoir releases and operational flexibility.

3.4.8 Reservoir

Full Reservoir Level (FRL)	2,006.0 masl
Minimum Draw Down Level (MDDL)	1,950.0 masl
Maximum Water level (MWL)	2,008.0 masl
Gross storage volume at FRL	240.53 million m^3
Gross storage volume at MDDL	78.54 million m^3
Live storage volume	157.90 million m^3
Surface area (at FRL)	4.25 km^2
Length of the reservoir	17.25 km at FRL

The Bunakha dam will impound a reservoir for storing water for multiple purposes. Upstream of the dam, the river slope is relatively mild, and for this reason, the length of the reservoir reaches 17.25 km. At Full Reservoir Level (2,006.0 masl), the reservoir provides a gross storage capacity of 240.53 million m^3, covering a surface area of about 4.25 km^2. The Minimum Drawdown Level (MDDL) is at 1,950.0 masl with a gross storage of 78.54 million m^3, yielding a live storage volume of 157.90 million m^3 between the operating levels. The Maximum Water Level is 2,008.0 masl. Figure 7 represents the reservoir at FRL.



Source: Updated DPR, Feb. 2026

Figure 7: Bunakha HPP's reservoir at full reservoir level

3.4.9 Permanent structure for power generation

The Project envisages an installation of 180MW (3 x 60 MW) on the river Wangchhu. It is expected that bulk of the power generated will be evacuated to India.

3.4.10 Tunnel and underground works

The Project includes extensive underground works comprising the intake structure, headrace waterway system, pressure shaft, high-pressure tunnel, distribution tunnels, underground powerhouse complex, transformer cavern, tailrace waterway system, access tunnels, ventilation tunnels, and tailrace outlet structures. Underground excavations will be undertaken primarily through drill-and-blast methods supported by rock reinforcement, shotcrete lining, steel supports, grouting, and concrete works.

Table 14: Details of tunnel and underground works

	Component	Activity	Key Dimensions
Headrace Waterway System	Headrace Tunnel	Excavation + concrete lining	Ø7.50 m, 248 m length, -10% incline
	Pressure Shaft	Vertical shaft excavation; concrete lining (upper bend) + steel lining (shaft/lower bend)	Ø7.50 m → Ø6.00 m, 75 m height
	High Pressure Tunnel	Excavation + steel lining	Ø6.00 m, 72 m length, -10% incline
	Distribution Tunnel	Excavation + steel lining	Ø4.25 m, 20 m length
	Upstream Manifolds (×3)	Excavation + steel lining	Ø3.00 m, 31–49 m lengths
	Downstream Manifolds (×3)	Excavation + concrete lining	Ø4.00 m, 36–54 m lengths
	Collecting Tunnel	Excavation + concrete lining	Ø6.00 m, 20 m length
	Tailrace Tunnel	Excavation + concrete lining	Ø7.50 m, 250 m length, 2% incline
Access & Ventilation Tunnels	Main Access Tunnel	Excavation with shotcrete support; invert lining with side drain	Ø8.40 m circular, 340 m length, -5.2% incline
	Cable Ventilation Tunnel	Excavation with shotcrete support; invert lining with side drain	Ø5.60 m horseshoe, 311 m length, -5.0% incline
Tailrace Outlet	Horizontal Outlet Transition	Excavation	Ø7.50 m → 5.90 m × 7.50 m transition section
	Surface Gate Shaft	Shaft excavation	15.50 m height
	Stoplog Gate Installation	Installation of vertical lift gate with winch hoist	5.90 m × 7.50 m gate size

Underground Powerhouse Complex	Powerhouse Cavern (PHC)	Large-scale cavern excavation	23.30 m (W) × 51.00 m (H) × 90.00 m (L); service bay, 3-unit bay, erection/unloading bay
	Staged Excavation	Multi-level excavation	9 levels from El. 1,829.00 m to El. 1,863.00 m
Transformer Cavern (TC)	Transformer Cavern (TC)	Cavern excavation	19.10 m (W) × 27.85 m (H) × 85.00 m (L); 40 m rock pillar separation from PHC
	Busduct Gallery	Underground excavation	Connection between PHC and TC

3.4.11 Additional residential buildings at CHP colony

The Bunakha HPP shall be operated under the management of the existing Chhukha HPP, for which additional manpower of 84 personnel will be required. To accommodate the additional manpower, a total of 0.80 acres will be required, which can be accommodated in the CHP colony premises.

Table 15: Total area required for residential buildings during the operational phase of the Bunakha HPP

Residential area - operation phase

SN	Employee	Type	Total heads	No of building	Area (Sq,m)
1	Officers	G+1	20.00	5.00	1000.00
2	General staffs	G+2	64.00	16.00	2,200.00
Total area for residential buildings					3,200.00
Total area in acres					0.80 acres

3.4.12 Replacement of the bridge at the Chanachen farm road

The existing Bailey Bridge over the Wangchhu River - currently limited to only 8 MT load capacity - must be replaced by a higher bridge (40 MT) to support heavier equipment and materials.

3.5 Construction Phase

The Project is expected to be constructed in a time frame of 6 years including 1 year for the pre-construction works - Box 2.

Box 2: Main milestones of the Bunakha HPP's construction schedule

It is expected that after submission of DPR and the ESIA, all the pre-construction works be initiated in January 2027 and completed by end of the same year. The main works are expected to start in April 2027 and to be completed by April 2032.

Source: DPR, 2026

The 205 m high RCC dam is the major component of the Project. The construction of the dam can only start after river diversion. The monsoon period lasts from June to September - this needs to be considered for planning of the diversion works. The excavation and major concrete works have to be completed outside that period (i.e., between October and May).

The location of project components is shown in Figure 8:. A description is added to the next sub-chapters.

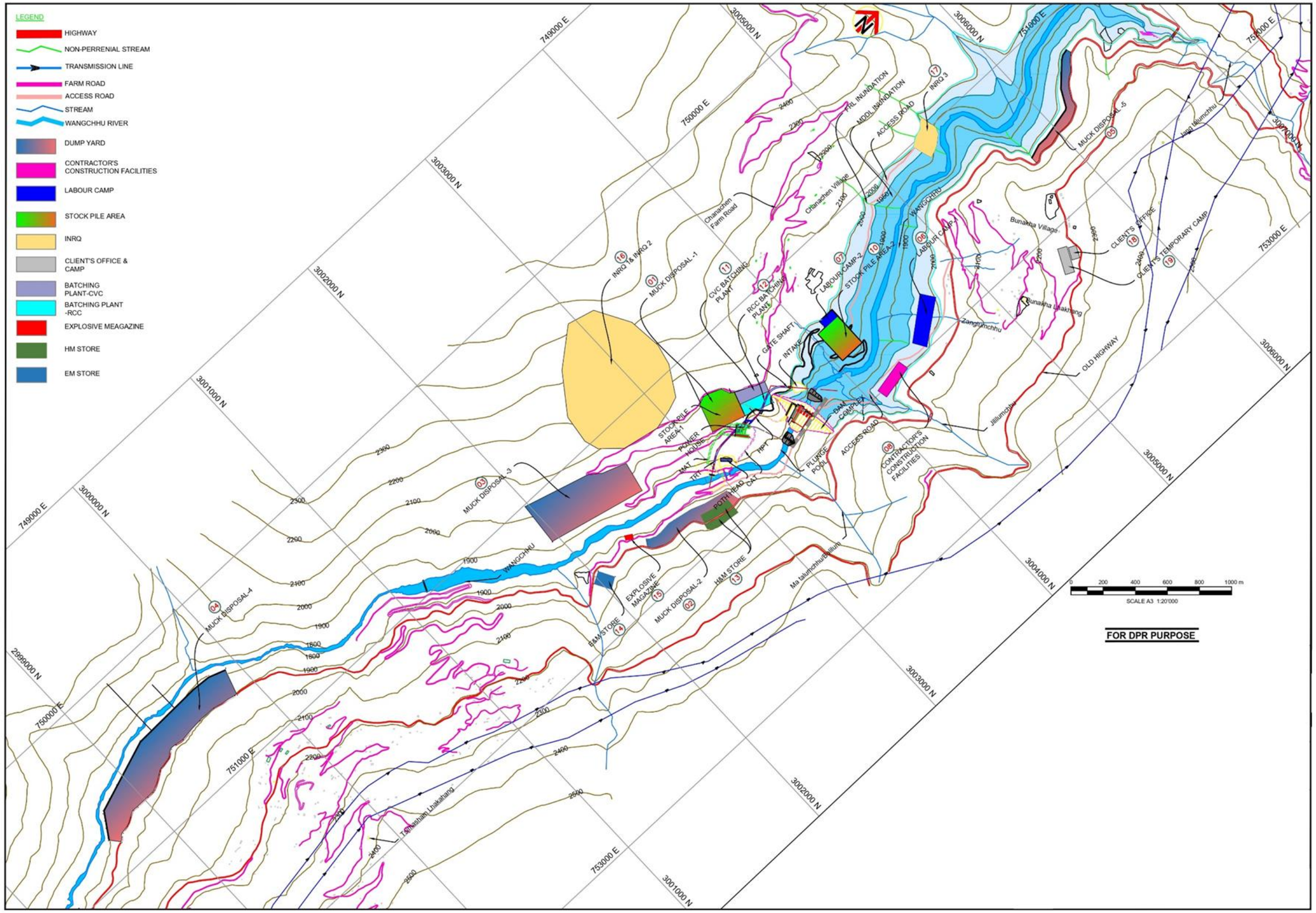


Figure 8: Location of the project facilities

3.5.1 Pre-construction works

The following major activities are to be completed within the 1-year pre-construction period:

- Land acquisition
- Construction of the access Project roads and upgrading of Chanachen Farm Road
- Construction of the Project bridge and upgrading of existing bridge along the Chanachen Farm Road
- Utility Setup (Power, Water, Telecom)
- Contractor Mobilization
- Employer & Contractor Camp & Office
- Construction of Batching & Crushing Plant
- Workshop & Maintenance Facilities
- Construction of Storage Yard
- Explosive Management
- RCC Lab setup
- Safety & environmental facilities
- Any additional survey & Investigations required.
-

Access Road and Bridge

The access road incorporates 6.70 km of new temporary roads, a 0.42 km road tunnel, and 7.50 km of upgraded existing roads. New roads utilize a standard 7 m formation width and a ruling gradient of 1 in 12.

Left Bank Dam Access: Accessible via the existing Thimphu-Phuentsholing Primary National Highway. Because the left dam abutment excavation reaches the highway level, a 30m section will be modified and routed through the slope berms to avoid a full road realignment.

Right Bank Dam Top Access: A new 0.30 km road branches from the Chanachen village farm road at RD 2.70 km at El. 1996.00 m. This road extends by 2.20 km to provide direct access to labor camp 2, stockpile area 2, the gate shaft, and the upstream cofferdam.

Dam Foundation Access: A 1.00 km temporary road branches off the Chanachen farm road before the existing Bailey Bridge, extending to the upstream cofferdam and requiring a box culvert with an approximate 10m span over the Matalumchhu stream.

Upstream Coffer Dam Access: The access road from the right bank dam top extends by approximately 2.75 km to connect labor camp, stockpile, top of gate shaft, and quarry INRQ-3.

Contractor Facilities Access: A temporary 1.70 km road connects the Primary National Highway near Bunagu village to the main upstream contractor facilities to minimize haulage distances.

Permanent Powerhouse Access: A 326 m Main Access Tunnel starts at an invert level of 1863.00 masl, safely above the 1859.20 masl Probable Maximum Flood level. The tunnel ascends for 80 m and then descends at 8% to the unloading bay in the powerhouse cavern at El. 1850.00 masl. A 90m branch splits at chainage 0+210 km to enter the transformer cavern.

Network Upgrades: The Chainachen farm road will be widened along a 5.5 km stretch to accommodate heavy equipment transit up to quarry INRQ3. The existing 8 MT Bailey Bridge over the Wangchhu River will be replaced by a permanent class 40R bridge with an 85m span to support

the maximum projected machinery weight of 40t. The 2.00 km Bugnagu farm road will receive bituminous blacktopping to manage dust emissions near residential areas.

SN	Description	Road length (km)	Remarks
A	**New Roads**		
1	Dam top right bank upto u/s coffer dam	2.75	Temporary road
2	Dam foundation & powerhouse (Left Bank) up to u/s coffer dam	1.00	Temporary road
3	Dam area to various construction facilities on left bank	1.70	Temporary road
4	Stockpile area to INRQ-3	1.25	Temporary
	Total:	**6.70**	
B	**Road Tunnel**		
1	Main Access Tunnel to PH	0.42	Permanent (under main package)
	Total	**0.42**	
B	**New Bridges**	**Span (m)/Type/Capacity**	**Remarks**
1	Bridge - 1	85/Permanent bridge/ 40R	Replacement of Chanachen farm road bridge
C	**Improvement of Existing Road**		
1	Chainachen village farm road	5.5 km	From highway till quarry site (INRQ3)
2	Bunagu farm road	2.00 km	

3.5.1.1 Residential and Non-Residential Complexes

Permanent Facilities: Managed under the existing CHPP located about 10km downstream. An additional manpower of 84 personnel requires 0.80 acres within the CHPP colony premises. The total residential plinth area is 3200 m^2, comprising 5 buildings (G+1) for 20 officers totalling 1000 m^2 and 16 buildings (G+2) for 64 general staffs totalling 2200 m^2. Administrative, health, and recreational amenities are already available at CHPP, so no additional non-residential buildings are planned.

Temporary Facilities: For 181 client personnel during peak construction, private buildings in Tshimalakha and Tsimasham will be leased. A contingency area at Bunagu village below the old highway identifies 2.47 acres for a temporary camp and 0.99 acre for a site office.

3.5.2 Main construction works

During the 60 months (5 years) of foreseen main construction works, the following is planned:

1st year

- Construction of twin diversion culverts (6.5 m × 12.7 m), including excavation and major concreting, to facilitate river diversion at the beginning of the following non-monsoon season.
- Establishment of project infrastructure, including aggregate crushing plant, batching plant, workshop and maintenance facilities, storage yard, and RCC laboratory.
- Design, shop drawings, manufacturing, factory acceptance testing, and delivery of diversion culvert electro-mechanical and hydro-mechanical components.
- Stripping and excavation of both dam abutments from El. 2010 m to El. 1856 m.
- Portal excavation, heading, and benching of the Main Access Tunnel (MAT, 425 m) and Cable Access Tunnel (CAT, 345 m) to provide access to the underground powerhouse complex.

2nd year

- Diversion of river flow through the diversion culverts and construction of upstream and downstream cofferdams during the non-monsoon season.
- Completion of all project infrastructure facilities.
- Excavation of dam foundation, foundation treatment, and consolidation grouting works.
- Commencement of excavation and support works for the underground powerhouse crown/pilot drift and transformer cavern following completion of MAT and CAT.
- Initiation of the Headrace Tunnel (HRT, 300 m) and side intake construction connecting the intake to the underground powerhouse.
- Continued design, manufacturing, procurement, testing, and delivery of electro-mechanical, hydro-mechanical, and transmission line components.

3rd year

- Construction of the main dam, including foundation to crest concreting from El. 1812.7 m to El. 2010 m, installation of embedded hydro-mechanical components, foundation galleries, and dam instrumentation. The dam, spillway, and water conductor system remain on the critical path and are completed within 60 months.
- Completion of design, manufacturing, procurement, testing, transportation, and delivery of all electro-mechanical, hydro-mechanical, and transmission line components within approximately 2.5–3 years.
- Underground powerhouse construction, including support works, earthmat installation, EOT crane beam installation, tail pit concreting, MIV floor construction, columns and beams, powerhouse concreting, and sequential installation of turbine-generator Units 1, 2, and 3. Civil works commence by Month 24, powerhouse concreting is completed within 18 months, and equipment erection is completed within four years from project start.
- Excavation and construction of the plunge pool following river diversion and cofferdam completion, with construction extending from October 2029 to January 2031.
- Construction of the Tailrace Tunnel (TRT, 275 m) from December 2029 to November 2030, followed by switchyard construction completed by November 2031.
- Plugging of diversion culverts in March 2032, followed by reservoir impoundment to minimum operating level between March and May 2032.
- Wet testing, commissioning of generating units, performance testing, and final project completion by October 2032.

3.5.3 River diversion

The revised project layout introduces a fundamentally different approach to river diversion by incorporating the system directly within the dam body, eliminating the need for external diversion tunnels. The diversion is achieved through a double culvert system integrated into the dam structure, located within the central blocks of the dam. The foundation of Block 13 has been

extended down to riverbed level, allowing the diversion structure to be founded on competent rock and constructed efficiently. A key advantage of this approach is that the excavation for the diversion culverts can be carried out in a single stage, independently of the main dam construction. This simplifies construction sequencing and avoids the need for extensive temporary works

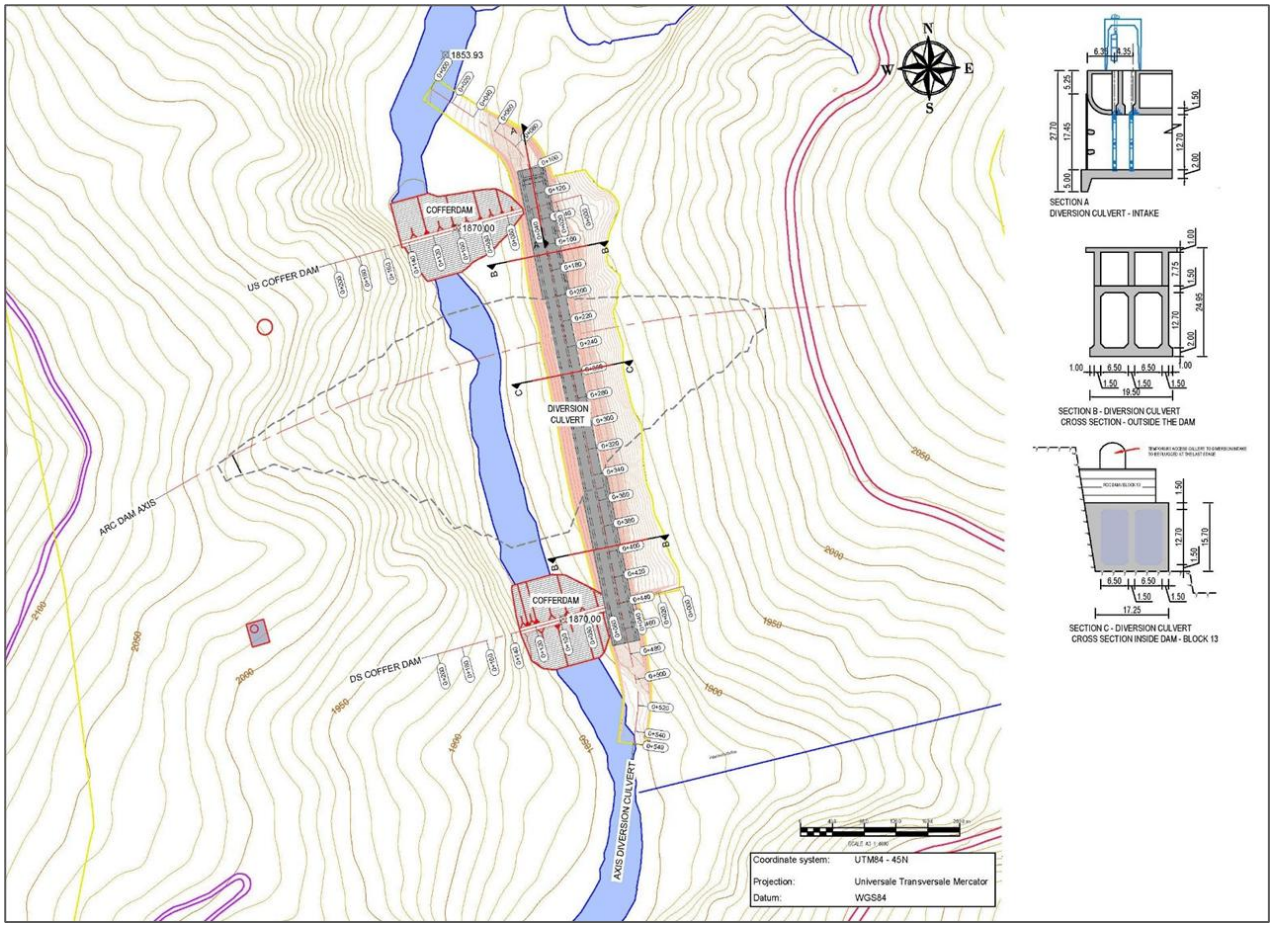


Figure 9: River diversion plan

3.5.4 Construction materials

Various materials will be sourced locally, including clay, aggregates and rock. Clay will be required for the temporary cofferdams; aggregate will be required for the roller-compacted concrete (RCC) and conventional concrete (CVC); and rock will be used for the temporary cofferdams and localized requirements of rock protection.

Cement and fly ash will be procured outside the Project site, as detailed below.

3.5.4.1 Quarries (coarse aggregate and rock)

Some rockfill will be required in the works, but in general the extracted rock will be processed into aggregate. The Project area is characterized by heterogeneous lithology consisting of gneiss, quartzite and garnets - these rock units will form the foundation of the dam.

Although the intention is to re-use excavated material wherever possible, the restricted stockpiling capacity, the material suitability and the timings of various phases of the works will require the opening of quarries. The DPR evaluated an initial set of eighteen (18) in-situ rock and riverbed

material quarries (INRQ). From these, ten (10) were recommended for detailed investigations for coarse aggregate and two (2) natural sand quarries were recommended for detailed investigations for fine aggregates.

Amongst all the identified deposits, the INRQ-3 located on the right bank of the Wangchhu river has been selected as the most suitable to obtain crushed coarse aggregate in concrete for wearing & non-wearing surfaces. The coarse aggregate is also found to be non-reactive and suitable for crushing to produce fine aggregate. The natural river sand quarries studied were found unsuitable for use in concrete.

The INQR-3 has a deposit of 13.99 million m^3, which is enough to meet the total requirement of the Project. The team identified another quarry deposit with 2.74 million m^3 at Damchu on the left bank of Thamchu (about 21 km upstream of the Bunakha dam axis) - INRQ-9. This quarry also meets the requirement for both wearing and non-wearing surfaces but is presently being exploited by a third party. In case of need, the Project will purchase materials from this quarry after carrying out necessary further tests.

3.5.4.2 Clay

The Consultant performed investigations along the left and right bank of the Wangchhu river and identified a few clayey soil deposits on both sides of the river within 2 km from the Bunakha dam axis. The quantity of clayey soil available is estimated at about 13,000 m^3 - this is sufficient for use as impervious material to meet the requirement of the coffer dams. Additional clayey soil, if required, is available below the road level along the Wangchhu river.

3.5.4.3 Cement

The DPR (2026) recommends procuring cement from the only Bhutanese Portland cement manufacturer - Penden Cement, which is located about 185 km from the Project site. The estimated requirement of Portland cement for construction of the 205 m high RCC dam & other structures is 538,356 metric tonnes.

3.5.4.4 Fly ash

The estimated requirement of fly ash for construction of the 205 m high RCC dam is 283,221 metric tonnes. The National Thermal Power Corporation of India (NTPC)'s Bongaigaon Power Station has been selected as the main source of fly ash for the Project. The Power Station is located in Kumguri, Kokrajhar, Assam, India, approximately 275 km away from the Bunakha HPP site.

3.5.5 Muck disposal (M-D) areas

The construction of various Project structures like coffer dam, diversion tunnel, dam and powerhouse complex, among others, will involve intense abutment, riverbed, alluvial, slope, bench, and foundation excavation works.

Some of the excavated material (estimated as 25%) will be integrated into the permanent works, while other materials will have to be disposed of in an appropriate manner in designated muck disposal areas/yards. The total volume of muck expected to be generated from various Project sites and the construction of access roads requiring to be disposed of is estimated as 5.65 million

m^3. To accommodate this, approximately 129.85 acres of state reserved forest land with an estimated disposal capacity of 6.09 million m^3 have been identified in the vicinity of the Project. Five (5) muck disposal yards are proposed at various locations to meet anticipated volume requirements for muck and also to allow flexibility in the contractor's operations. Additional information regarding the muck disposal area and its corresponding stability controls per site in section 13.5.24 Muck Disposal Plan.

The designated sites comprise state reserved forest land identified as suitable for the safe disposal and long-term stabilization of excavated materials. No privately owned land is proposed for permanent muck disposal. The location, area, estimated disposal capacity, existing land use, and ownership status of each muck disposal site have been considered during site selection to minimize environmental and social impacts. Any temporary land use requirements associated with transportation, access, or site preparation activities have been assessed as part of the Project and are addressed through the ESIA and Resettlement Plan, where applicable.

3.5.6 Contractors' construction facilities (CCFs)

The contractors which will be awarded the major packages will require space to build their offices, colonies for their regular employees, labour camps at various sites, site offices, stores, material storage, spare parts & miscellaneous items, workshops, parking yards for equipment, fabrication yard, and others.

Adequate space has been identified at different locations according to the estimated numbers of staff stationed and the area required for the contractors' construction facilities (CCFs). Most of the CCFs are planned within the reservoir submergence area or integrated with the dumping sites to minimize impacts on the environment and private land. Out of the total required area of 44.56, only 8.71 acres are planned as independent facilities, while the remaining areas fall within the reservoir or are combined with dumping yards. The detailed area requirements are provided in Table 17.

Table 16: Contractor's construction facilities (CCFs) type and area required for the Bunakha HPP

SN	Description	Location	Area (Acres)	Remarks
A	**CCFs within other Project component/facilities**			
1	Labour camp-1	Near Bunagu village below highway	7.41	Within reservoir submergence area
2	Labour camp-2	Below Chanachen village	1.24	
3	CCF- material, storage, offices, lab, workshop	Near Bunagu village below highway	3.50	
4	Stockpile area-2	Below Chanachen village	8.70	
5	Stockpile area-1	On MD-1	11.50	With MD-1
Total (A):			***32.35***	
B	**Independent CCFs**			
1	Batching Plant-CVC	Near MD-1	3.50	

SN	Description	Location	Area (Acres)	Remarks
2	Batching Plant-RCC	Near MD-1	3.73	State reserved forest land
3	H&M store	Near MD-3	2.36	
4	E&M store	Chanachen farm road junction with highway	2.20	
5	Explosive Magazine	Chanachen farm road junction with highway	0.37	
		Total (B):	***12.16***	
		Total A+B (in acres)	***44.51***	

Source: Updated DPR, Feb. 2026

Workshop

A central workshop for heavy earth moving equipment and transport vehicles shall be set up at the Project site considering open space, a parking area, and covered/semi-covered repair sheds. The workshop shall comprise facilities for the engine repairs and overhauling, transmission, torque converter repair shops, auto-electrical shops, machine shop, tyre repair shop, welding and fabrication shops, chassis repairs, body and seat repairs, denting/painting, and maintenance yard, among others.

Explosive Magazines

In order to cater for blasting requirements of various work sites, it is planned to provide one permanent mother explosive magazine. Portable site magazines of 1,000 kg capacity will also be provided to cater to the day-to-day requirement of explosives. All safety codes and regulations prescribed by the RGoB in this respect will be followed and magazines will be suitably guarded round the clock. Necessary approvals will be taken from the concerned authorities for these magazines.

Crushing Plants

One aggregate crushing plant and one and sand crushing plant with the capacity of 1,250 tonnes per hour (TPH) will be located within the quarry to process the quarry excavated material.

Batching and Mixing (B&M) Plants

Considering the concreting requirements of the various work sites, one B&M mixing plant of 120 m3/hr capacity for CVC (peak production of concrete for powers house and dam complex), and one B&M mixing plant of 120 m3/hr capacity for RCC are planned near M-D (muck disposal yard) 1.

3.5.7 Construction water requirements

The water required for various construction activities and structures (including the labour camp) will be sourced from various perennial streams available in the Project area mostly by gravity (Table 17).

Table 17: Water sources for the construction of the Bunakha HPP

SN	Project Component	Proposed Water Source

1	DGPC's facilities (camp & office)	Share with Bunakha community
2	Labour camp-1	Jililumchhu
3	CCF-1	Jililumchhu
4	CVC/RCC Plant	Stream u/s of Chhukha HPP
5	H&M store	Matalumchhu

Source: Updated DPR, Feb. 2026

3.5.8 Construction power requirements

The estimated peak power demand for the Project is about 9.5 MW. The nearest grid substation to the dam site is at Chhukha, where a 336 MW power generation station is located. The power generated is evacuated to different parts of Bhutan as well as in India at 220 kV and 66 kV. The power required for the Project's construction can be catered from Chhukha HPP's existing 66 kV system, which is catered to meet the power requirements within Bhutan.

It is proposed to provide supplemental power aggregating to 5,000 kVA from diesel generators (DG), as a stand-by energy source in case of interruption of the grid's supply.

Table 18: Construction power requirements of the Bunakha HPP

RCC Power Requirements	Value	Unit
Crushing Plant (1250t/hr) at (2kW/t)	2800	kW
Concrete Batching Plant (600m3/hr) at (2kW/m3)	1500	kW
Conveyor System (two nos.)	2500	kW
Other Construction Requirements		
Ventilation & compressors	600	kW
Dewatering	200	kW
Site Lighting	200	kW
Other		
Offices	200	kW
Colonies	400	kW
Workshop (wielding, fabrication, etc.)	200	kW
Total	**8600**	**kW**
Losses as a percentage	20	%
Losses	1.72	MW
Peak Requirement	10.32	
Diversity Factor (DF)	0.9	
Peak requirement after applying DF	9.42	MW
Minimum Power Capacity	**9.5**	**MW**

3.5.9 Workforce requirements during construction

The Bunakha HPP is expected to follow the same construction approach used in current HPP in the country. Infrastructure works will be executed by Bhutanese contractors through an open competitive bidding process. Major civil and hydro-mechanical works—such as the dam and powerhouse—will be implemented under item-rate contracts, with designs provided by DGPC. Electro-mechanical works will be procured through an EPC contract, also via open competitive bidding. A dedicated BHPL will be established to oversee implementation, while the main civil works will be carried out by contractors and OEMs (original equipment manufacturers).

The Project's workforce requirements are divided into three phases: pre-construction, peak construction, and operation and maintenance (O&M). Planning and estimating the Project management personnel for each phase is based on experience from similar hydropower projects.

Pre-construction

During the pre-construction phase, the primary activities will focus on developing project infrastructure (access roads to various project components, bridges, temporary offices, temporary colonies and water supply, among others). These works are planned to be carried out by Bhutanese contractors through open competitive bidding. The staffing needs for the Project authority during this phase are estimated at approximately 39 persons (Table 19).

Table 19: Workforce requirements of the Project authority for the pre-Construction period of the BHPP

SN	Designation	Nr.	Total
1	**MD's Office**		
a.	Managing Director (MD)	1	4
b.	PA to MD	1	
c.	Office Assistant	1	
d.	Driver	1	
2	**Contracts & Procurement Division**		
a.	Executive Engineer	1	6
b.	Asst. Executive Engineer/Asst. Engineer	1	
c.	Store In-charge	1	
d.	Office Assistant	1	
e.	Driver	2	
3	**Infrastructure Division**		
a.	Executive Engineer	1	12
b.	Asst. Executive Engineer/Assistant Engineer	1	
d.	Junior Engineer/Section Officer	2	
e.	Supervisor	3	
g.	Office Assistant	2	
h.	Driver	3	
4	**Environment & Social Management Unit**		
a.	Environment Officer	1	5
b.	Social Safeguard Officer	1	
c.	Assistant Environment Officer	1	
d.	Occupational Health and Safety (OHS) officer	1	
e.	Communication Officer	1	
5	**Administration and Finance Division**		
a.	Administrative Officer	1	12
b.	Finance Officer	1	
c.	Personal Officer	1	
d.	Liaison officer cum Labour Officer	1	

SN	Designation	Nr.	Total
e.	Asst. Finance Officer	1	
f.	IT Officer	1	
g.	Asst. IT Officer	1	
h.	Cashier	1	
i.	Office Assistant	2	
j.	Driver	2	
Total Manpower		**39**	

Peak-construction

During the peak-construction period, the focus will shift to advancing the core works, resolving critical technical issues, and maintaining strict financial oversight. Administrative functions, financial management, quality assurance at the construction sites, and securing necessary clearances will also remain essential responsibilities.

Throughout this stage, the BHPL will continue to give priority to engaging local personnel. Based on current planning, the BHPL will require a total of 181 staff members during the peak construction phase.

Project Supervision Consultant (PSC) will operate as a second tier of oversight, providing day-to-day supervision, monitoring, compliance verification, and reporting support to BHPL throughout the peak-construction period. The PSC team will be led by a PSC Team Leader/Resident Engineer and will maintain a minimum ESHS staffing complement of five specialists - covering environmental, social and resettlement, occupational health and safety, biodiversity, and community liaison/stakeholder engagement functions. The PSC's Environmental, Social and Resettlement, and OHS Specialists will report directly to BHPL's Environment, Social, Health and Safety Management (ESHS) Unit on ESHS performance, ensuring an independent verification layer that complements BHPL's internal compliance monitoring, as illustrated in the organizational structure below.

The corresponding organizational structure is shown below.

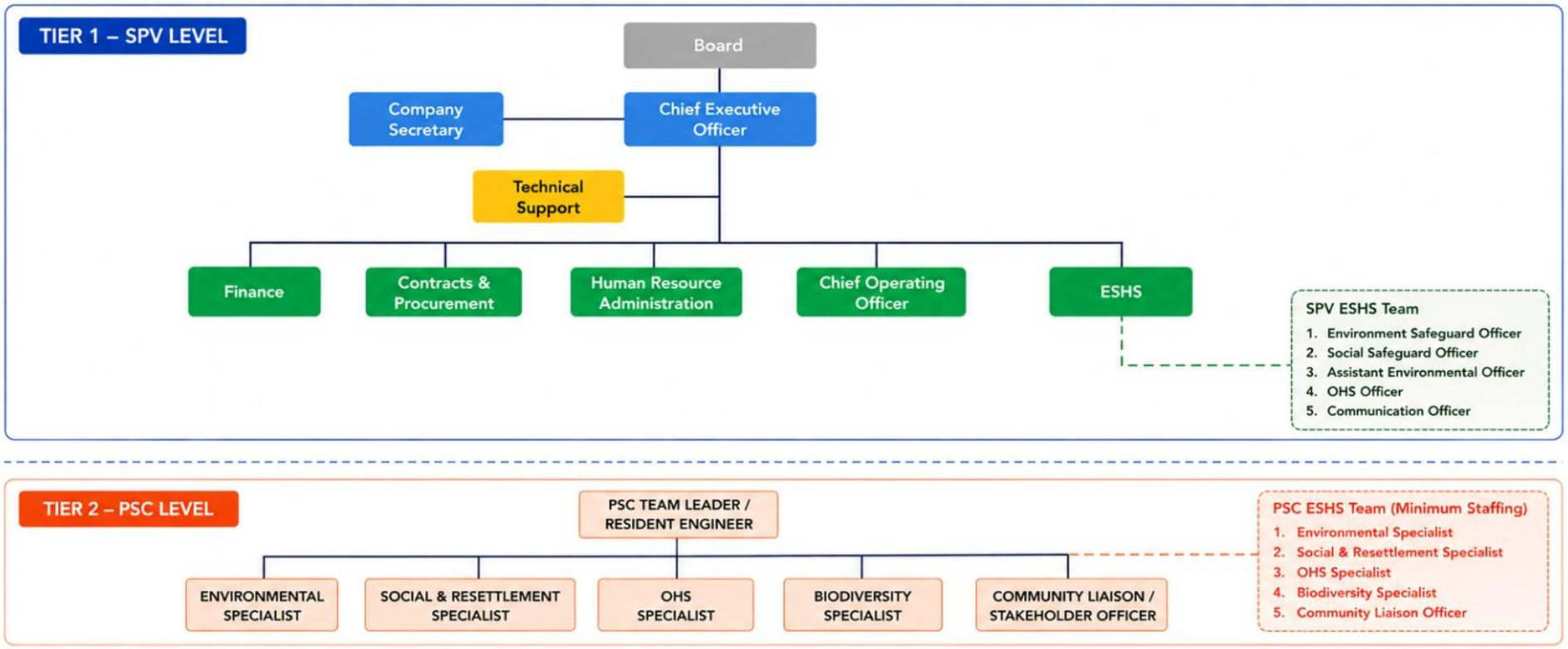


Figure 10: Foreseen organizational structure of the BHPL during the peak-construction period of the BHPP

Based on the experience from similar projects in the country, the estimated manpower required by the contractor during the peak construction stage is estimated to be about 970 as detailed in Table 20.

Table 20: Estimated workforce for the contractor during the peak-construction stage of the Bunakha HPP

Category	Skilled	Semi-skilled	Unskilled	Total	Key roles
Civil	200	250	250	700	Skilled: RCC specialists, surveyors, steel fixers, crane operators. Semi-Skilled: Formwork carpenters, welders. Unskilled: Laborers, helpers.
EM	60	40	30	130	Skilled: Electricians, turbine technicians, instrumentation engineers. Semi-Skilled: Cable pullers, panel installers.
HM	50	30	20	100	Skilled: Welders (pressure pipes), valve technicians. Semi-Skilled: Gate installers, riggers.
TL	15	10	15	40	Skilled: Tower erectors, HV cable jointers. Semi-Skilled: Linepersons.
Total	325	330	315	**970**	-

3.5.10 Transmission lines

The projected load demand in the immediate vicinity of the project is deemed negligible, with the expectation that nearly all generated power will be exported to India. Power will be transmitted from the underground transformer cavern via two 220 kV cables through the Cable and Ventilation Tunnel to the surface pothead yard located close to the tunnel portal. From the pothead yard, two overhead lines will form a 1x D/C loop-in and loop-out configuration with the existing single circuit 220 kV Chukha-Jamjee line over a connection distance of nearly 2.5 km. A new 1xD/C 220 kV line passing the plant in 2 km distance gives the opportunity to LILO one circuit also.

3.6 Operational Phase

In order to understand the operational conditions of the Project and estimate the energy generation from the HPP system, a mass-balance reservoir model was prepared during the Updated DPR (Chapter 8), while the output from it also serves as valuable information to assess the impact of the regulation to Wangchu River flows provided by the storage reservoir.

Along with the hydrological input as presented, several other non-hydrological parameters, mainly the physical and operational parameters of dam and reservoirs are defined. Those required parameters are obtained and considered as presented in the tables below.

Table 21: Reservoir parameters of the Bunakha HPP

Maximum Water level (MWL)	EL 2008 m
Full Reservoir Level (FRL)	EL 2006 m
Min. Draw down Level (MDDL)	EL 1950 m

Gross Storage	240.53 Mcum
Live Storage	157.90 Mcum
Area under Submergence at FRL	4.25 Sq. km
Length of the Reservoir	17.25 km at FRL of EL 2006 m

The Project shall operate normally between the Full Reservoir Level (FRL) and the Minimum Drawdown Level (MDL). As a large dam, the Project shall be designed for Probable Maximum Flood (PMF) and assure a combination of PMF and Glacial Lake Outburst Flood (GLOF).

For the simulations carried out, the Bunakha reservoir was divided into three different zones:

- Inactive zone: The lowest part of the reservoir (up to elevation 1950 masl) which stores dead water and sediment over the dam's lifetime.
- Conservation/active zone: The main operating storage area between 1950 masl and the Full Supply Level (FSL) at 2006 masl, used for power generation and controlled by the guide curve.
- Flood control zone: The upper zone above FSL and below the dam crest, used only during floods when excess water flows through the spillway.

As a guide rule of the reservoir operation, the following boundary conditions are defined in the DPR (Update Feb. 2026) in terms of firm operating hours per season:

- Wet season: 6 hours/day
- Dry season: 6 hours/day

These defined operating periods are based on reasonable assumptions regarding the reservoir's limited storage capacity. They were further validated through a sensitivity analysis that considered both milder and more intensive peaking scenarios. The results indicate that, for 95% of the long-term hydrological record, the Bunakha reservoir will be able to sustain maximum discharge and generation capacity during the designated 6-hour daily peaking window. This peaking operation can be distributed throughout the day—particularly in the dry season—most plausibly split into two periods corresponding to morning and evening high-load demand, consistent with the current run-of-river plant operations along the Wangchu River.

During the wet season, excess discharge will be stored in the Bunakha reservoir and subsequently released during the dry months. As an additional boundary condition, the reservoir is to be operated sustainably, meaning that it should be fully replenished within a 12-month cycle. Due to the reservoir's relatively small storage volume compared with the river's total annual runoff, its influence on the overall flow regime of the Wangchu River is minor, as demonstrated in Chapter 8 of the DPR.

BHPL shall consider the progressive integration of emerging digital technologies to enhance dam safety prediction, environmental monitoring, and cumulative impact management during the operational phase. These may include Earth Observation (EO) satellite imagery for continuous reservoir rim stability monitoring, reservoir sedimentation mapping, and catchment land cover change detection, AI-assisted data analytics to support predictive dam safety assessment, online real-time water quality sensors deployed at key monitoring stations for continuous automated measurement, and Digital Twin modelling of the dam and reservoir to simulate operational scenarios, flood routing, and cumulative cascade impacts.

3.6.1 Workforce requirements during operation

The Bunakha HPP will be operated under the management of the existing Chhukha Hydropower Plant (CHP), taking advantage of its proximity and the established operational capacity of CHP under DGPC. After accounting for resource sharing with CHP, the additional personnel required for the operation and maintenance of the Bunakha HPP is estimated at 84 persons, reflecting the use of modern automation technologies in the power plant. The organizational structure for the O&M phase is presented below.

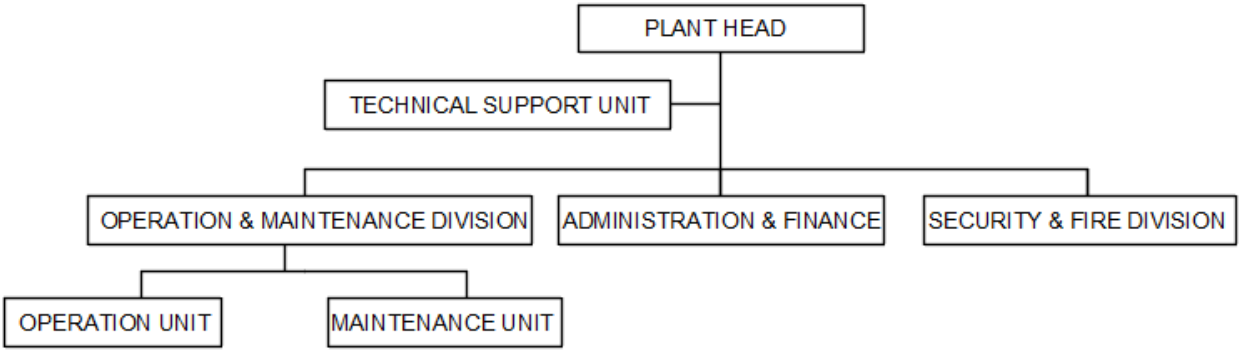


Figure 11: Foreseen organizational structure of the Project authority during the operation period of the Bunakha HPP

4 Area of Influence

4.1 Background and Definitions

The Area of Influence (AoI) of a project is defined as “the total area likely to be affected by both on-site and off-site impacts from project activities, assets and facilities, including associated facilities. The size of a project’s area of influence, as well as the environmental and social risks and impacts within the area, can vary considerably depending on the nature of the project” (IFC, 2012: Guidance Notes on the IFC PS). The AoI facilitates the identification of the biological, physical and socio-economic elements to be considered in the ESIA.

According to ADB’s SPS (2009), the AoI encompasses:

- (i) the primary project site(s) and related facilities that the borrower/client (including its contractors) develops or controls, such as power transmission corridors, pipelines, canals, tunnels, access roads, borrow pits and disposal areas, and construction camps;
- (ii) associated facilities that are not funded as part of the project (funding may be provided separately by the borrower/client or by third parties), and whose viability and existence depend exclusively on the project and whose goods or services are essential for successful operation of the project;
- (iii) areas and communities potentially affected by cumulative impacts from further planned development of the project, other sources of similar impacts in the geographical area, any existing project or condition, and other project-related developments that are realistically defined at the time the assessment is undertaken; and
- (iv) areas and communities potentially affected by impacts from unplanned but predictable developments caused by the project that may occur later or at a different location.

The 2024 revision of the 2018 Guidelines for Development of Hydropower Projects of Bhutan (the “Hydropower Guidelines”) establishes that the AoI shall be defined in terms of direct and indirect effects and needs to include surrounding communities, activities along roads, and downstream areas subject to project influence.

Direct impacts are, according to the Hydropower Guidelines, those “under the control of or caused by the project”, such as:

- changes in land ownership and/or land use (“footprint") including reservoir(s), industrial areas, camps and colonies, resettlement areas, reforestation areas, transmission rights-of way, access roads, quarries, muck areas etc.;
- changes in environmental quality including river flows, noise, air and water quality, wildlife and fish populations, traffic, vibrations, dust, visual quality, etc.;
- and changes in livelihoods, living standards, health and safety, and cultural heritage for directly-affected people.

Indirect or second/higher order impacts are, according to the Hydropower Guidelines, those “outside the control of the project”, such as:

- induced changes in regional demographics, employment, business and tax revenues, changes in prices and property values, supply chain effects, environmental quality, and other factors.

The spatial extent affected by indirect impacts are generally more difficult to define than areas of direct impact due to the varying nature of secondary and induced environmental and social effects. In Bhutan, and in accordance with national Hydropower Guidelines and prevailing ESIA practices, indirect impact areas are therefore commonly defined using a combination of administrative jurisdiction boundaries (e.g., affected Gewogs), hydrological catchment/basin considerations, and fixed-distance influence zones. For the BHPP, the indirect area of influence has accordingly considered the full extent of affected Gewogs, relevant sections of the Wangchhu basin, as well as a 10 km zone[5] surrounding major hydropower infrastructure, and a 400 m corridor along transmission line alignments.

4.2 The Bunakha HPP's Area of Influence

In consideration of the above, the direct AoI for the Bunakha HPP is delineated by applying a 5-kilometer buffer around the Project's main components, and the indirect AoI by applying a 10-kilometer buffer. Further details can be read in Box 3. Figure 12 shows a geographical representation of the Project's direct and indirect AoI.

Box 3: The AoI of the Bunakha HPP

The **direct AoI - 5 km buffer** around the Project's main components encompasses:

- Direct Impact Zone (DIZ): consists of the direct project footprint. The DIZ is delineated by applying a 500-m buffer around the footprints of several high-impact project components, including the dam, quarry, batching plants, worker camps, and other key ancillary facilities
- Social Area of Influence: Encompasses communities affected by land acquisition, resettlement, livelihood changes, and cultural impacts. Includes both physically displaced and economically affected persons
- Upstream and downstream river systems: to assure consideration of hydrological changes (e.g., flow regime, sediment transport, fish migration) that may occur up and downstream of the dam
- Environmental Area of Influence: included in all three above.
- For involuntary resettlement purposes, the direct AoI additionally encompasses the host community identified to receive the physically displaced household, as required under ADB SPS (2009) Involuntary Resettlement requirements.

The **indirect AoI - 10 km buffer** around the Project's main components encompasses:

- The direct AoI
- The remaining buffer area: Rangsigan, Tesbji, Lhagochen, Aringkha, and TenChhukha
- The indirect AoI explicitly includes key regional infrastructure serving the Project area, specifically: (i) Phuentsholing-Thimphu Highway (AH48), which runs through Chhukha Dzongkhag and will experience increased heavy vehicle traffic during construction, (ii) Chanachen farm road with Bailey bridge over Wangchu River (ii) Tshimalakha Hospital, which will serve as the primary healthcare facility for the construction workforce and (iii) Chhukha Central School and may experience increased traffic safety risks. These facilities are assessed as receptors under IESC#16 (Infrastructures) in Chapter 8.

Regional Service Hub:

[5] The delineation of indirect impact areas is based on Bhutan Hydropower Development Guidelines and prevailing hydropower ESIA practice in Bhutan, which commonly apply administrative, hydrological, and distance-based criteria to define broader areas potentially influenced by project-related indirect and induced impacts.

- The indirect AoI also encompass key regional service centers that will provide essential services (healthcare, education, banking, markets, fuel, lodging) to the Project workforce during construction, including the Chhukha Dzongkhag headquarters (~12 km), and Tshimalakha (hospital, school, market),
- These hubs are included in the AoI because increased demand from the construction workforce (peak ~970 contractor personnel plus ~181 BHPL staff) may place additional pressure on the capacity of local health, education, and commercial services, constituting an indirect social impact requiring monitoring.

This buffered approach encompasses key geographical features and communities:

- Gewogs: The AoI covers parts of several Gewogs, including Chapcha, Bongo, and Geling in the south, and extends north to include parts of Doga and Shapa.
- Upstream communities: The 5 km buffer extends far upstream to include settlements such as Chapcha and Dawakha.
- Downstream communities: The AoI includes the key downstream settlements of Tsimasham and Tshimalakha.
- Communities within the DIZ: The core project area and its 500 m buffer are located near the communities of Chanachen, Bunakha, and Nayakha.

4.2.1 Treatment of Induced Impacts

Project's AoI explicitly includes areas and communities potentially affected by unplanned but predictable developments enabled by the Project.

For Bunakha HPP, these include: in-migration and settlement growth along access roads and near construction camps; expansion of informal commercial activity (teashops, shops, rental accommodation) in Chanachen, Bunakha, and Nayakha in response to workforce presence; and increased pressure on regional service hubs (Tshimalakha, Chhukha Dzongkhag headquarters) as described above.

These induced impacts are assessed qualitatively in Section 13 (Socio-Economic Impacts).

4.3 Interaction Hotspots

In addition to the spatial and thematic AoI defined above, specific "interaction hotspots" are identified where labour influx is expected to create the highest frequency of direct interaction between the Project workforce and local communities, and therefore the highest risk of SEAH, GBV, communicable disease transmission, and social friction.

These hotspots include:

- Chanachen and Bunagu, given its immediate proximity to the main quarry, crushing units, batching plants, and Labour Camp 1 and 2;
- access roads connecting labour camps and CCFs to local markets and settlements;

These interaction hotspots shall be subject to targeted monitoring under the SEAH/GBV prevention measures described in Section 13.5.9 labour management plan and 13.5.17 public health delivery/human health management plan.

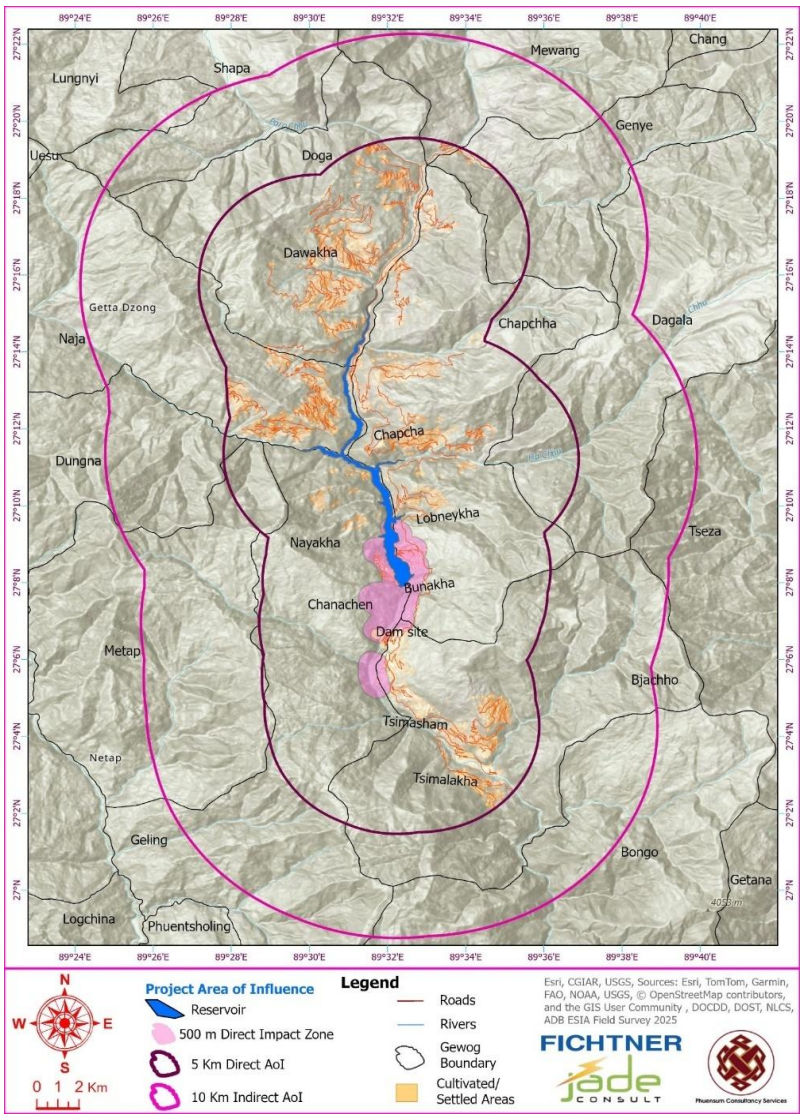


Figure 12: Overview of the Bunakha HPP's Area of Influence

5 ESIA Scope, Objectives and Methodology

The main objective of the ESIA is to anticipate and assess any negative and positive impacts and risks the Project might pose in the physical, biological and human environment during pre-construction, construction, operation and decommissioning phases, and to define mitigation measures to avoid, reduce or compensate significant E&S impacts and risks to achieve tolerable levels of acceptance.

The steps undertaken for the ESIA study include:

- analysis of the current environmental and social situation in the area of Project implementation and influence (baseline);
- analysis of the requirements for impact assessment in compliance with the relevant international standards and national legislation and guidelines.
- comprehensive identification of environmental and social impacts and risks based on the updated DPR, available data and studies, and the results of the field surveys and baseline appraisal,
- assessing the potential significance of the impacts and risks, and
- development of mitigation and monitoring measures for the impacts and risks identified compiling them into the E&S Management Plan.

The ESIA includes the identification and description of the potential impacts of the Project (during pre-construction, construction, operation and decommissioning) on the biological and physical resources, the socio-economic and socio-cultural environment, community and occupational health and safety, and climate. The assessment of impacts considers all project components as e.g. onsite and offsite facilities and operations, access roads, disposal areas, workers camps, etc. When carrying out analyses, projections and assessments, the Project Area of Influence (Chapter 4) is considered.

5.1 Methodology for Data Collection

The data gathering commenced at the inception stage and continued through the ESIA. The methodology used for the compilation of the data comprised the following:

- Literature review: Environmental and social data relevant to the Bunakha HPP in form of previous studies and reports was collected from open and governmental internet sources, reviewed and analysed.
- Collection of satellite images and maps
- Interviews and meetings with authorities, NGOs, the scientific community, inhabitants, and project-affected people.
- Baseline surveys:
  - the Consultant's international and national specialists performed thorough on-site investigations at the Project site and surroundings to identify environmentally and socially sensitive receptors such as natural habitats, plant and animal species, current land cover and use, landscape characteristics, cultural heritage, houses and other structures affected by the Project, and other issues related to possible displacement, compensation and livelihood restoration.
  - Environmental and social data have been georeferenced and maps have been prepared for the entire investigation area.

Table 22 shows an overview of the surveys that have been undertaken.

Table 22: Nature and status of the baseline surveys undertaken for the Bunakha HPP

Type of survey	First season: **Dry/Spring** March and April 2025	Second season: **Monsoon/Summer** July, August and September 2025	Third season: **Post-monsoon/Autumn** November and December 2025	Fourth season: **Winter** January 2026
Physical environment: air, noise, soil quality, and traffic	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	*Not applicable*	*Not applicable*
Physical environment: water quality	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Not initiated[6]
Terrestrial biodiversity - flora and habitats	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Not initiated[6]
Terrestrial biodiversity - fauna: mammals, avifauna, and herpetofauna	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Not initiated[6]
Aquatic biodiversity - fish, macro-invertebrates, periphyton, phytoplankton, zooplankton, and related water quality parameters	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Concluded Report in **Error! Reference source not found.**	Not initiated[6]
Socio-economic survey	Concluded Report in **Error! Reference source not found.**	*Not applicable*	*Not applicable*	*Not applicable*
RAP survey	Concluded Reporting in Chapter **Error! Reference source not found.**	*Not applicable*	*Not applicable*	*Not applicable*

[6] The fourth season monitoring (winter) was deferred to ensure the ESIA reporting meets the critical 120-day disclosure deadline required by ADB. From a technical perspective, this omission is low-risk, as winter water quality and biodiversity parameters typically show little deviation from dry season conditions (Bhutan's climate is characterized by a dry winter, meaning winter conditions closely resemble the typical "dry season"). Consequently, the pending winter surveys shall be undertaken by the contractor prior to construction, while the current comprehensive dataset serves as a valid basis for the ESMP and impact assessment.

5.1.1 Physical environment surveys methodology

The methodology for the physical baseline environmental survey was designed to be systematic, scientifically robust and compliant with both national regulatory requirements and international best practice. The approach involved conducting field surveys during three distinct seasons (dry, monsoon, and post-monsoon) to capture environmental variability, using strategically selected monitoring locations and adhering to standardized sampling and analysis protocols.

5.1.1.1 Survey periods

The baseline environmental data was collected through a structured, multi-season field survey program designed to capture the distinct environmental variations within the Project's sub-tropical, monsoon-influenced climate.

Wind, air quality and noise

Surveys were conducted during two distinct seasons to establish baseline conditions. Concurrent meteorological monitoring of wind speed and direction was conducted to understand pollutant dispersion patterns during the dry, dusty season and the wet monsoon season.

- Dry/Spring season: April 14-23, 2025
- Wet/monsoon/Summer season: July 21-28, 2025

Water quality

The TOR for the Consultancy stipulated a comprehensive four-season monitoring program (dry/spring, wet/monsoon/summer, post-monsoon/autumn and winter). The impact assessment is based on the findings from three of the four required surveys[6], covering the following periods:

- Dry/Spring season: April 14-23, 2025
- Wet/monsoon/Summer season: July 21-28, 2025
- Post-Monsoon/Autumn season: November 24-27, 2025

Soil quality

The soil sampling program was conducted over the two survey periods. The primary objective was to establish a definitive pre-construction baseline at all relevant project locations, especially after finalizing component layouts.

- Dry/Spring season (April 14-23, 2025): An initial survey was conducted at four preliminary locations (SSP-1 to SSP-4).
- Wet/monsoon/Summer season (July 21-28, 2025): Following the finalization of the Project footprint, the sampling program was expanded. A baseline was established at four new distinct locations (SSP-5 to SSP-8), strategically selected to correspond with the confirmed sites for the main workshop, labor camp, and batching plants.

Traffic count

Vehicular traffic was monitored at Bunagu Junction along Asian Highway 48 (AH48) using a manual counting method over a 16-hour period (6:00 AM to 11:00 PM) during both dry and wet seasons. Trained enumerators recorded vehicles by category, including cars/SUVs, light and

heavy commercial vehicles, buses, and two-wheelers, as well as their direction of movement (towards Thimphu and Phuentsholing).

To account for potential seasonal variations in traffic volume and composition, surveys were conducted during both seasons:

- Dry/Spring season: April 23, 2025
- Wet/monsoon/Summer season: July 24-26, 2025

5.1.1.2 Survey locations

A network of monitoring locations was strategically established across the AoI to assess the baseline conditions for air, noise, water, and soil. The selection of these sites was based on their proximity to proposed Project components (dam, batching plants, workshops, camps), their representation of sensitive environmental and social receptors (villages, temples, heritage sites), and their ability to capture upstream and downstream conditions.

Wind, Air, and Noise Quality

Ten monitoring stations (ANSP-1 to ANSP-10) were established to measure local wind conditions (speed and direction), ambient air quality, and background noise levels (Figure 13). These locations include sensitive receptors like the Bunakha Lhakhang (ANSP-4) and the villages of Nayakha (ANSP-9) and Chanachen (ANSP-10), as well as sites for proposed project infrastructure such as the damsite (ANSP-3) and the consolidated batching plants (ANSP-10).

Water Quality

A network of ten water quality sampling points (SW-1 to SW-10) was established to characterize the Project area's hydrological systems, specifically (Figure 14):

- Rivers/tributaries (assessed against Class B River standards): 6 sites sampled via SW-1, SW-2, SW-3, SW-4, SW-6, and SW-8.
- Community drinking water sources (assessed against stricter National Drinking Water standards): 4 sites sampled via SW-5, SW-7, SW-9, and SW-10.

The monitoring plan was implemented progressively:

- Eight locations (SW-1 to SW-8) were sampled during the first season (dry). These sites were selected to monitor the main river body (Wangchhu River) upstream (SW-1) and downstream (SW-2) of the proposed dam, key tributaries, including Jhililumchhu (SW-3, SW-4), Motolumchhu (SW-6), and Zanteylum chhu (SW-8), as well as two previously identified community water sources (SW-5 and SW-7).
- Following the finalization of Project component locations near Chanachen and to ensure comprehensive coverage of all critical community water sources, the network was expanded during the second and third surveys with the addition of two new sites:
  - Nayakha Chhu (SW-9): A key stream directly utilized by Nayakha village as a drinking water source.
  - Chanachen Village spring water (SW-10): A primary drinking water source for the Chanachen community.

Soil Quality

Eight soil sampling points (SSP-1 to SSP-8) were identified to assess the pre-construction soil quality (Figure 15). The sampling was conducted progressively across two non-overlapping phases to adapt to major layout optimizations during design:

- Initial campaign (dry season / April 2025): Locations SSP-1 to SSP-4 were sampled exclusively during this period. At the time of this initial survey, the proposed concrete batching plants and other major infrastructure were planned for the left bank of the Wangchhu River (Bunakha side). These samples established the baseline for that original footprint. Because soil chemistry does not fluctuate seasonally in the same manner as water or air, these sites were not re-sampled during the wet season.
- Revised footprint campaign (wet season / July 2025): As the design progressed, the layout was optimized, shifting high-impact facilities like the concrete batching plants and aggregate crusher plants to the right bank of the river (Chanachen side). Consequently, four entirely new sampling locations (SSP-5 to SSP-8) were established and sampled exclusively during the July survey to capture the pre-construction baseline of these newly finalized footprints. These specifically target:
  - Labour camps (SSP-5): potential for contamination from domestic wastewater and improper waste disposal.
  - Main workshop area and vehicle maintenance yards (SSP-6): risk of contamination from hydrocarbons (e.g., fuel, oil, lubricants) and solvents).
  - RCC/CVC batching plants and aggregate crusher plants (SSP-7 and SSP-8): risk of soil alkalization from cement and concrete additive spills),

Traffic count

The traffic count surveys were done on the Asian Highway 48 (AH48) at the Bunagu Junction (Figure 16).

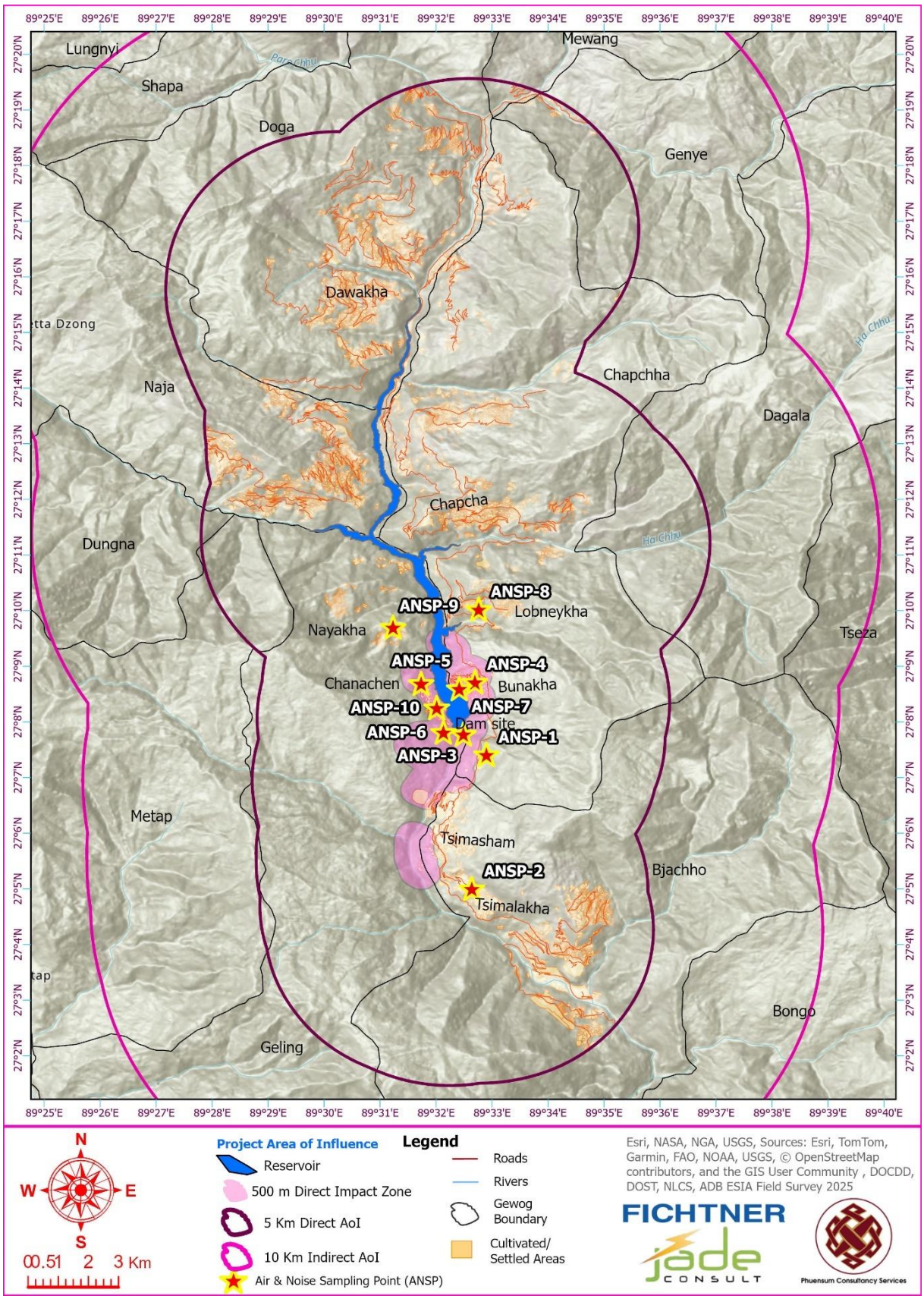


Figure 13: Wind, air and noise sampling points (ANSP) within the Bunakha HPP' AoI - dry and wet seasons

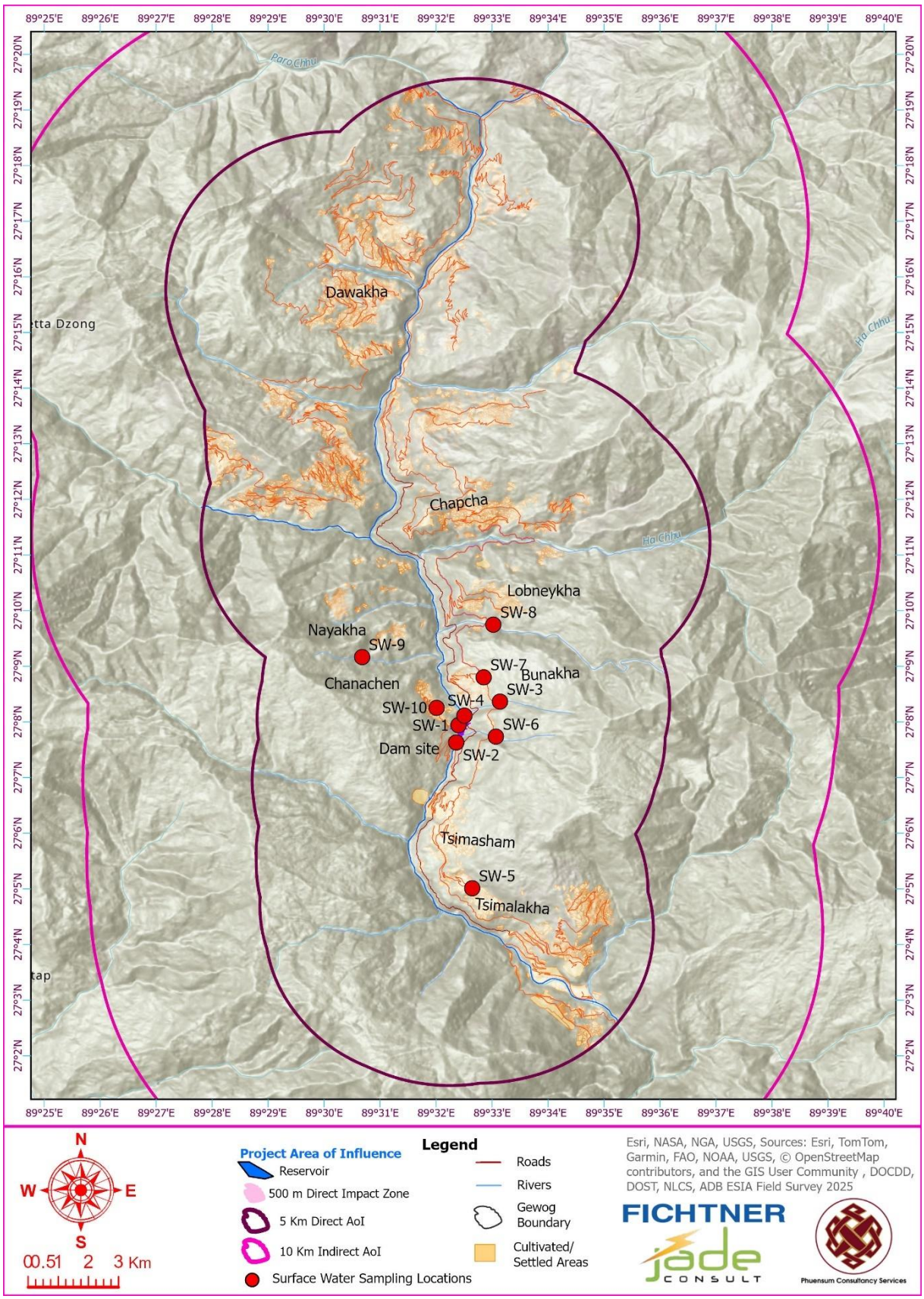


Figure 14: Surface water (SW) sampling locations within the Bunakha HPP' AoI - dry, wet and post-monsoon seasons

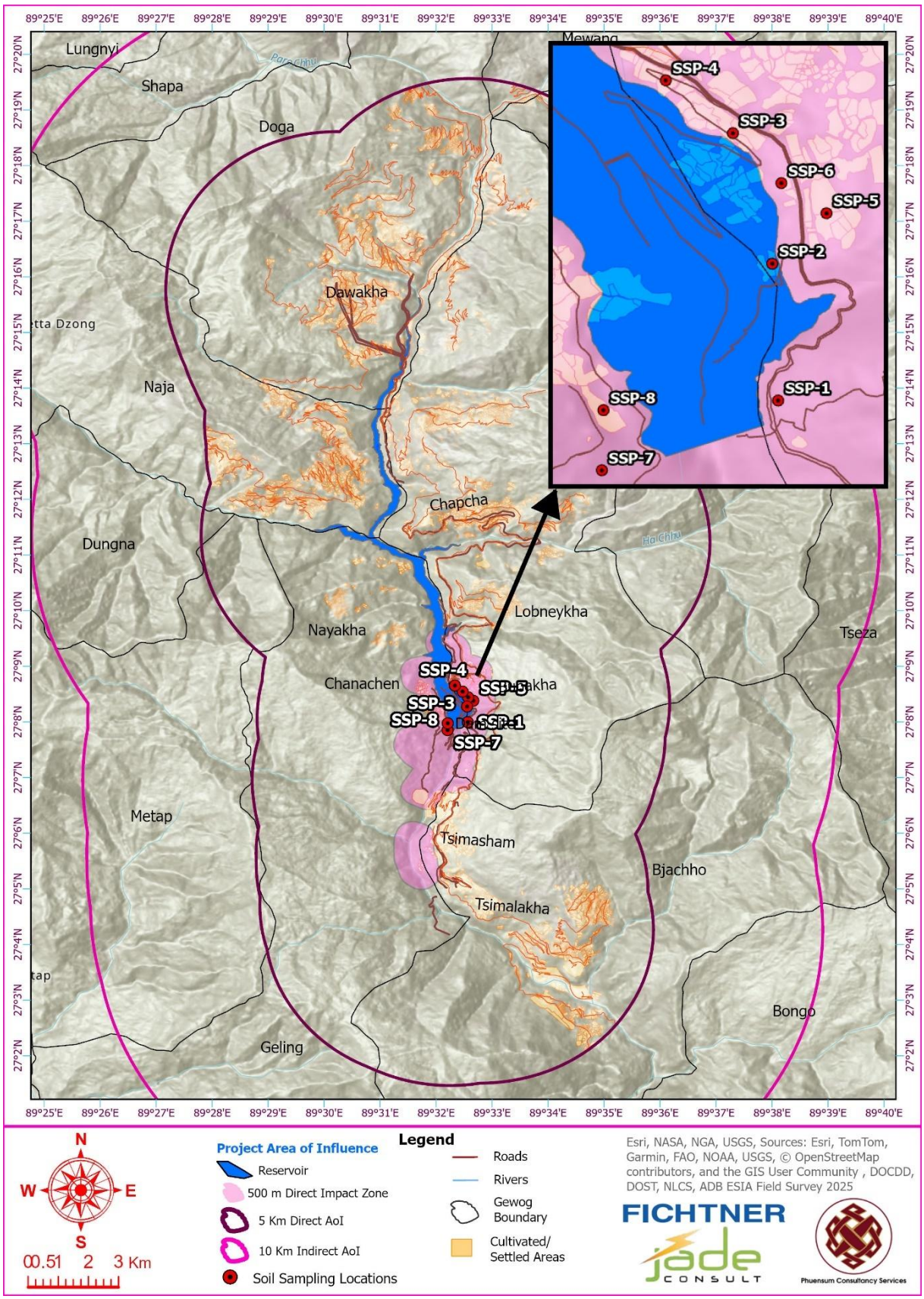


Figure 15: Soil sampling points (SSP) within the Bunakha HPP's AoI - dry (SSP-1 to 4) and wet (SSP-5 to 8) seasons

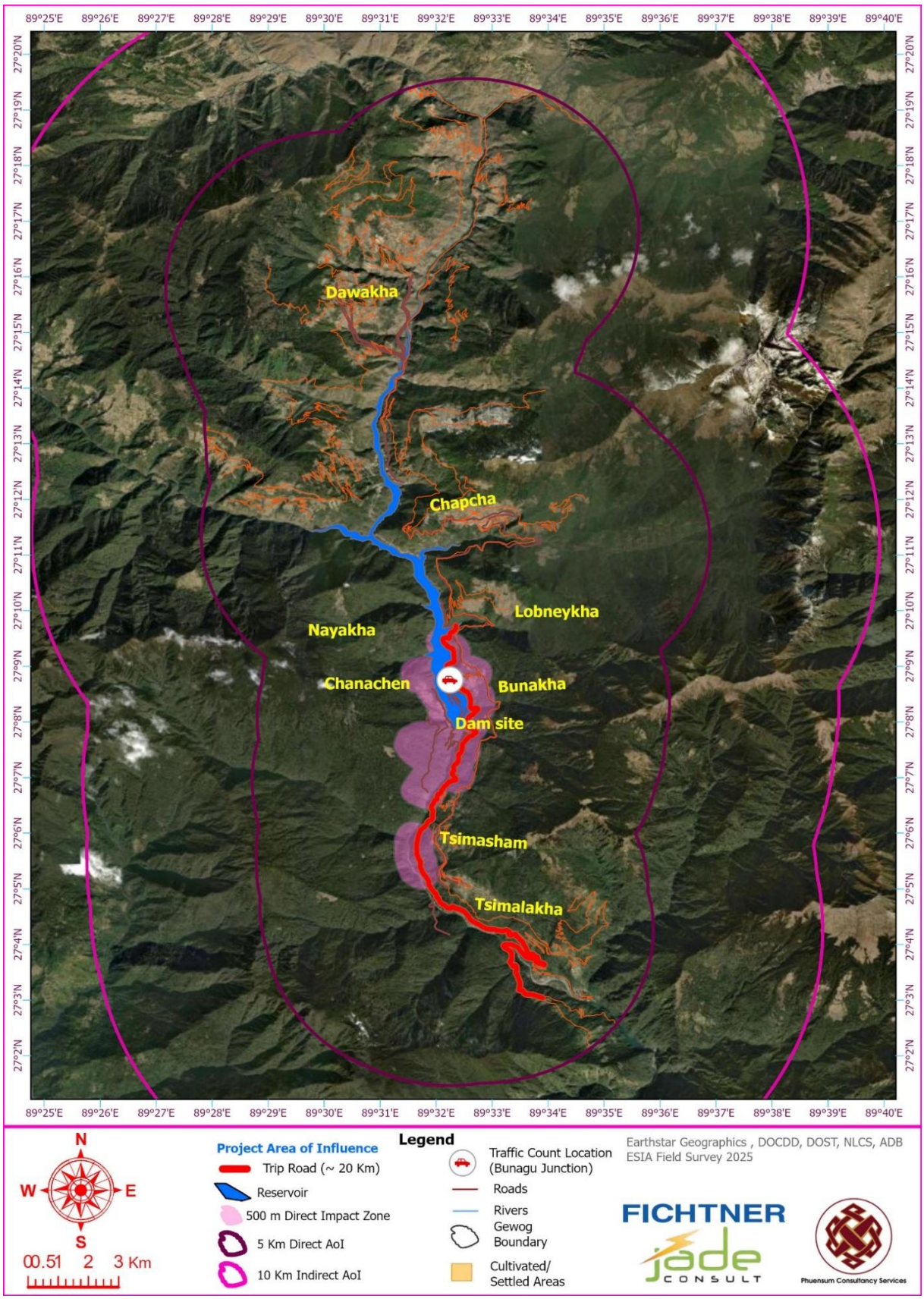


Figure 16: Traffic surveys location within the Bunakha HPP's AoI (assumed 20 km travel distance in the Direct AoI)

5.1.1.3 Survey procedures

To ensure the collection of accurate, reliable, and scientifically defensible data, a standardized set of sampling and analysis procedures was followed for all environmental components during both the dry and wet season surveys. The methodologies adhere to national guidelines and best international practices.

Air Quality and Meteorological Monitoring

Ambient air quality and wind parameters were monitored continuously over a 24-hour period at each of the ten ANSP stations. Monitoring was conducted using calibrated AQM-09 Ambient Air Quality Monitoring Stations (manufactured by Henan Oceanus). This integrated system was used to collect data for the following parameters, in accordance with the requirements of Bhutan's Environmental Standards 2020. This survey was conducted by ENGEO Consultancy, which specializes in baseline air quality monitoring.

- Air Quality Parameters:
  - Particulate Matter (PM) (total suspended particles (TSP), PM_{10}, and $PM_{2.5}$)
  - Gaseous Pollutants: Sulphur Dioxide (SO_2), Oxides of Nitrogen (NOx), Ozone (O_3), and Carbon Monoxide (CO).
- Meteorological Parameters:
  - Wind speed (m/s)
  - Wind direction.

This concurrent collection of pollutant and meteorological data is essential for understanding local dispersion patterns and interpreting the air quality results. The monitoring was conducted to establish a representative baseline of atmospheric conditions under typical daily cycles for both seasons.

Ambient Noise Monitoring

Concurrent with the air quality monitoring, ambient noise levels were measured at all ten ANSP stations using the integrated noise sensor of the AQM-09 monitoring station. Equivalent Continuous Noise Levels (Leq) were recorded over a 48-hour period on each season to capture full diurnal cycles. The data was then aggregated to establish representative baseline levels for:

- Daytime (Leq d): 6:00 am to 10:00 pm
- Night-time (Leq n): 10:00 pm to 6:00 am

Water Quality Sampling and Analysis

The water quality assessment involved both on-site measurements and laboratory analysis of collected samples.

- On-site measurements: At each of the ten surface water sampling sites, key parameters were measured directly in the field using calibrated, portable multi-parameter probes. These included pH, Dissolved Oxygen (DO), water temperature, and electrical conductivity.
- Laboratory Analysis: Water samples were collected from each site using clean bottles, stored in cool boxes, and sent to a certified laboratory in Kolkata, India for testing. The laboratory analysed a wide range of water quality indicators, including total suspended solids (TSS), turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates, phosphates, heavy metals, and both total and faecal coliform bacteria. All testing followed the

standard procedures outlined by the American Public Health Association (APHA) to ensure reliable and accurate results.

Soil Quality Sampling and Analysis

At each of the eight total locations sampled (four in April 2025 and four in July 2025), a consistent methodology was applied. Composite samples were collected from two distinct depths:

- Surface Samples (0-20 cm): To assess the baseline for potential contamination from surface spills and dust accumulation.
- Subsurface Samples (20-50 cm): To evaluate the baseline condition for parameters that may leach through the soil profile.

Samples were collected using standardized tools, stored in clean, labelled bags, and dispatched for analysis at Qualissure Laboratory Services in Kolkata, India, a NABL accredited laboratory. The samples were analysed for key parameters relevant to potential project impacts, such as pH, heavy metals, nutrients, and Total Petroleum Hydrocarbons (TPH) at high-risk locations.

Traffic Count Survey

Vehicular traffic was monitored at Bunagu Junction on Asian Highway 48 (AH48) using manual count methods over a 16-hour period (6am-11pm) during both the dry and wet seasons. Data was collected by enumerators who recorded vehicles by type (e.g., cars/SUVs, light commercial vehicles, medium/heavy trucks, buses, two-wheelers) and by their direction of travel (Thimphu-bound and Phuentsholing-bound). This methodology allowed for the determination of baseline traffic volume, composition, and diurnal flow patterns.

5.1.2 Terrestrial biodiversity surveys methodology

A three-season ecological monitoring program for terrestrial biodiversity was designed to establish comprehensive baseline conditions of the Project's AoI prior to its implementation. The survey covered terrestrial fauna and flora, focusing specifically on vegetation, mammals, avifauna, butterflies, moths, and herpetofauna (reptiles and amphibians).

5.1.2.1 Survey periods

Terrestrial biodiversity surveys were conducted during three distinct seasons:

- Dry/Spring season: April 4-14, 2025
- Wet/monsoon/Summer season: August 30 - September 10, 2025
- Post-monsoon/Autumn season: November 21 - November 30, 2025.

5.1.2.2 Survey locations

During the dry/Spring season, 27 plots were sampled, while during the two subsequent seasons, the number of surveyed locations increased to 39. The surveyed locations are shown in Figure 17.

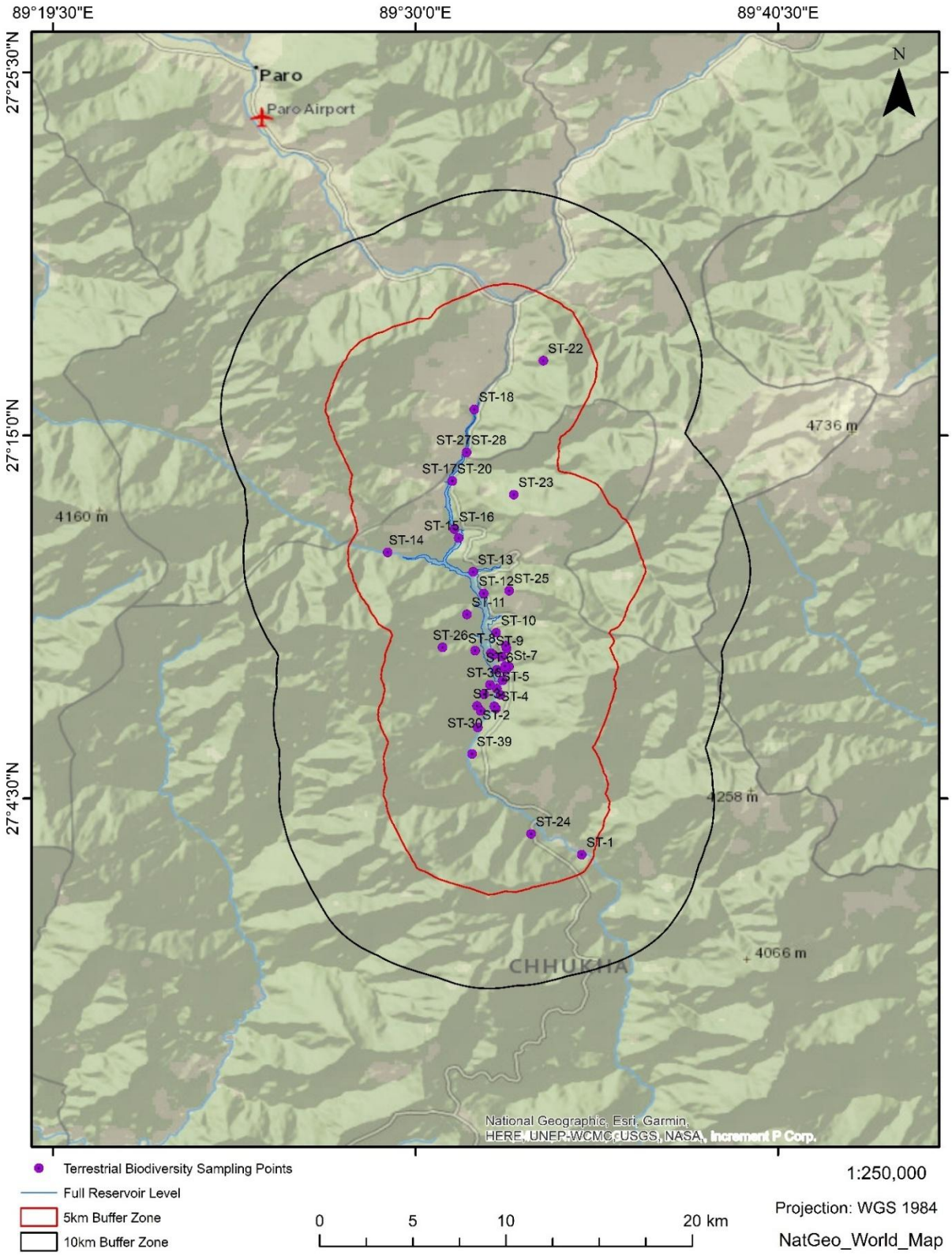


Figure 17: Terrestrial biodiversity survey points (ST-#) within the Bunakha HPP's AoI

5.1.2.3 Survey procedures

To ensure robust and comparable data collection, the terrestrial biodiversity surveys employed a range of standardized survey methods. For each species encountered during the surveys, parameters such as coordinates, date, and associated habitat characteristics were recorded in the datasheet. In addition to these field methods, a qualitative data collection approach was used by conducting face-to-face interviews with local villagers and roadside workers to gather anecdotal evidence and confirm the presence of herpetofauna diversity in the Project area. Further details are described in the following chapters.

5.1.2.3.1 Terrestrial flora and habitats

Initially, available aerial imagery was used to delineate different forest and vegetation types, as well as their status, and transfer this information onto topographic maps to support the field surveys.

The vegetation sampling plots were identified on the topographic maps for all forest types and statuses within the AoI. The quadrant method was applied to record biodiversity, forest status, wood volume, and other non-timber forest products (NTFPs).

1km x 1km grids (on the 1st season) and 4km x 4km grids (on the 2nd and 3rd seasons) were laid over the direct AoI. Sample plots were selected on alternate grids with focus on the inundation area (one each on right and left banks). The points falling on agricultural/developed areas and inaccessible areas were adjusted in different grids. The AoI representative samples for different forest types was selected as per LULC, 2016.

A sample plot of 20mx20m was laid in every identified location with a minor plot of 2m x 2m at its center (Figure 18). Plots were not established within 200 m from vehicular roads and 100 m from the footpath. Within the plots, information such as GPS coordinates, altitude, slope, soil and forest types, canopy density, any direct or indirect animal traces (tracks, scat, hair, rooting and scratch marks), degree of biotic disturbances, among others were recorded.

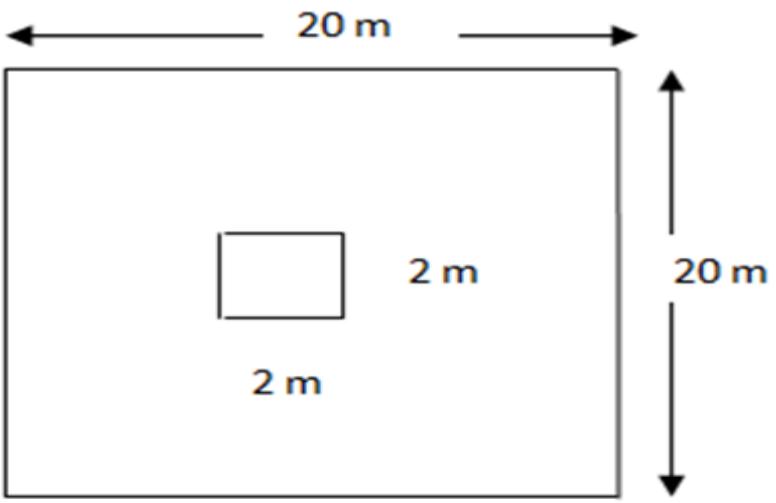


Figure 18: Schematic representation of the sample plots used in the terrestrial vegetation field surveys within the Bunakha HPP's AoI

Vegetation higher than 1.3m was recorded in the tree data form, including shrubs. The regeneration of tree species was recorded within the minor plot of 2m x 2m, including the ground cover (herbs

and shrubs) and saplings of tree species. Individual tree species of 10 cm DBH (diameter at breast height) were also recorded.

5.1.2.3.2 Mammals

The assessment began with the desktop collection and review of available secondary literature and terrestrial fauna maps to identify typical and critical wildlife habitats. For the 2nd and 3rd season surveys, an additional specific focus was placed on target species informed by then ongoing Critical Habitat Assessment - see Chapter 7.2.5.3.

The mammals monitoring was conducted through transect surveys in the sampled biodiversity monitoring grids described in Chapter 5.1.2.3.1. Within each grid, trail transects were walked covering major habitat types within the grid. Mammal sightings and mammal signs for all species, such as tracks, scats, dung, scratch marks, etc., encountered on the trail transects were recorded. If the area was inaccessible, 3–5 shorter trail transects of at least 1 km each were searched for mammals and mammal signs.

GPS locations were recorded at every 500 m in the datasheet, even if no animal or sign was observed. In cases of direct sightings, species, GPS location details, number of animals seen, and the sex and age of the animals were recorded. For encounters of animal signs, the surveys team recorded species, sign type, GPS location details, and habitat type. In the case of animal trails, each trail set (and not each pugmark) was considered as one sign. If an animal continued to walk along a trail for a long distance in the same direction, then this was considered as one sign, whereas if no sign was seen on the track for over 50 m, encountering a fresh track set was considered a new sign.

Photographic records with proper scale reference and GPS location were taken if there was difficulty in sign identification. Informal discussions with local communities were conducted, and any information on animal observations or reports was documented in the field record. All team members followed established safety protocols and used appropriate personal protective equipment (PPE) at all times.

5.1.2.3.3 Avifauna

The avifauna assessment began with the desktop collection and review of secondary literature and avifauna maps to identify typical and critical bird habitats. Field surveys in the direct impact zones were focused on birds through direct observation. Different methods were used for different species groups:

- Common species were adequately documented through trail transects or other survey methods, and the MacKinnon Bird Listing was followed for this purpose; as advised by DGPC.
- Rare species were surveyed using trail transects combined with special search efforts such as combing or flushing in their habitats, which enabled the collection of sufficient data. For instance, the Wood Snipe, being both rare and cryptic, required special search or acoustic survey methods.
- Colonial species were recorded by counting colonies, as counting individual birds of large colonies was difficult.
- Nocturnal species, which were active during dusk, were adequately surveyed using night vision binoculars and by listening to bird calls.

Observations were made using binoculars along trails, ridges, riverbanks, and rock faces, with particular attention to nesting birds. Surveys were extended up to 2,100 masl.

The avifauna was monitored through transect surveys in the sampled biodiversity monitoring grids described in Chapter 5.1.2.3.1. Within each grid, a 1 km trail transect was laid out. If the grid encompassed more than one habitat type, as many 1 km trails transects as possible were run. Trails were walked along an existing trail (footpath, animal track, or road), with birds being recorded on either side of the observer. The distance at which a bird was seen or heard from the transect line was recorded as an absolute measure, perpendicular to the trail transect line, using a laser range finder.

5.1.2.3.4 Herpetofauna

The herpetofauna (reptiles and amphibians) data collection techniques adhered to established protocols commonly utilized within herpetology. The selection of survey locations for the monsoon and post-monsoon seasons was strategically guided by the dry season terrestrial habitat assessments. This phased approach ensured the optimal identification of potential microhabitats suitable for herpetofauna, including riparian zones, forested areas, human settlement area, and rocky outcrops.

The methodology was multifaceted and designed to gather a comprehensive set of observations. The core of the survey relied on direct observation and systematic microhabitat surveys. This involved actively searching for herpetofauna in various environments, including under logs and rocks, within leaf litter, and in aquatic or semi-aquatic habitats.

To supplement the field work, a citizen science and social knowledge integration approach was utilized. This included conducting interviews with local residents, foresters, and experienced herpetologists to gather valuable anecdotal information regarding historical species presence, distribution, and local ecological knowledge. Additionally, a preliminary species checklist was compiled by reviewing published articles, scientific papers, and credible social media platforms, such as dedicated Facebook groups page, where reliable herpetofauna sightings and identification are shared.

Visual Encounter Surveys

The direct observation technique employed the Visual Encounter Survey (VES) method along pre-determined transects at designated survey stations.

Surveys were conducted during both diurnal and nocturnal periods to account for the activity patterns of different herpetofauna species. Each period utilized distinct traversal approaches to optimize detection. Within the established transects, data on terrestrial, arboreal, and aquatic species were systematically documented in their respective ecological niches. Nocturnal observations were facilitated using high-voltage headlamps to locate and identify species in low-light conditions.

Systematic Microhabitat Search Method

A systematic approach involving targeted exploration of microhabitats was employed across the designated survey stations. This method, coupled with direct observational techniques and visual encounters, proved highly effective for revealing elusive species that seek shelter within their natural environments.

Specifically, searches were conducted in microhabitats such as the bark of dead trees, decomposing wood, and leaf litter. These focused searches were performed once along the predetermined transects within each survey station.

5.1.2.4 Data analysis procedures

Field data was collected by the trained field technician in direct supervision of the technical national expert in the designated format provided in the printed forms. The data was then entered into a spreadsheet. Once the data entry was done, the list of species, frequency, and density was estimated.

Bird density was estimated by calculating the area surveyed (survey length × average survey width) and expressing the number of birds observed per hectare. Species diversity was measured as the number of species per unit area, and the Importance Value Index (IVI) was calculated based on species dominance.

5.1.3 Aquatic biodiversity surveys methodology

A three-season ecological monitoring program for aquatic biodiversity was designed to establish comprehensive baseline conditions of the river system prior to Project implementation. Specifically, the aquatic surveys aimed at:

- documenting the diversity and abundance of fish, macroinvertebrates, zooplankton, and phytoplankton
- assessing physicochemical water parameters at key locations, including environmental flow (E-flow) sites.

5.1.3.1 Survey periods

Aquatic biodiversity, including water quality surveys were conducted during three distinct seasons:

- Dry/Spring season: March 25-31, 2025
- Wet/monsoon/Summer season: August 27 - September 10, 2025
- Post-monsoon/Autumn season: November 25 - December 04, 2025

5.1.3.2 Survey locations

A stratified systematic sampling design was followed to assess aquatic ecosystems across the Project's AoI. Sampling sites were selected to represent diverse habitat types (namely pools, riffles, and runs) and diverse ecological conditions, including upstream and downstream of the Bunakha dam, tributaries, diversion reaches, and areas affected by peaking flows. Site selection prioritized ecological significance, accessibility, and habitats of vulnerable or endangered species. Key geomorphological and flow characteristics were also considered to ensure a representative and comprehensive ecological assessment.

Considering the above, the aquatic biodiversity and water quality surveys were planned for a total of 28 sampling sites (Figure 19), distributed as follows:

- Sites A1 to A4: Upstream the Bunakha inundation area
- Sites A5 to A10: Bunakha inundation area
- Sites A11 to A14: Between Bunakha dam and Chhukha dam
- Sites A15 to A17: Between Chhukha dam and Tala dam

- Sites A18 to A28: Downstream of Tala dam

From these, 5 sites (A13 to A17) were considered for E-flow related data sampling.

Not all sites yielded samples for every component on all seasons. For example, samples were not collected in all sites due to heavy rainfall and high runoff from the extreme October 2025 rainfall, which disrupted habitats and reduced organism availability; some logistical constraints limited access to site A8 (Haa Chhu confluence) and site A7 (Tanalung stream confluence) during the dry/spring season - observations for these sites were therefore based on nearby accessible areas; measurements of physical parameters like width, depth, and velocity were conducted only where feasible and estimated where direct measurement was not possible; etc. In this sense, a total of 17 sites were effectively sampled during the dry/Spring season, and a total of 24 sites were sampled in the other two seasons. Details of restrictions can be consulted in **Error! Reference source not found. Error! Reference source not found.**.

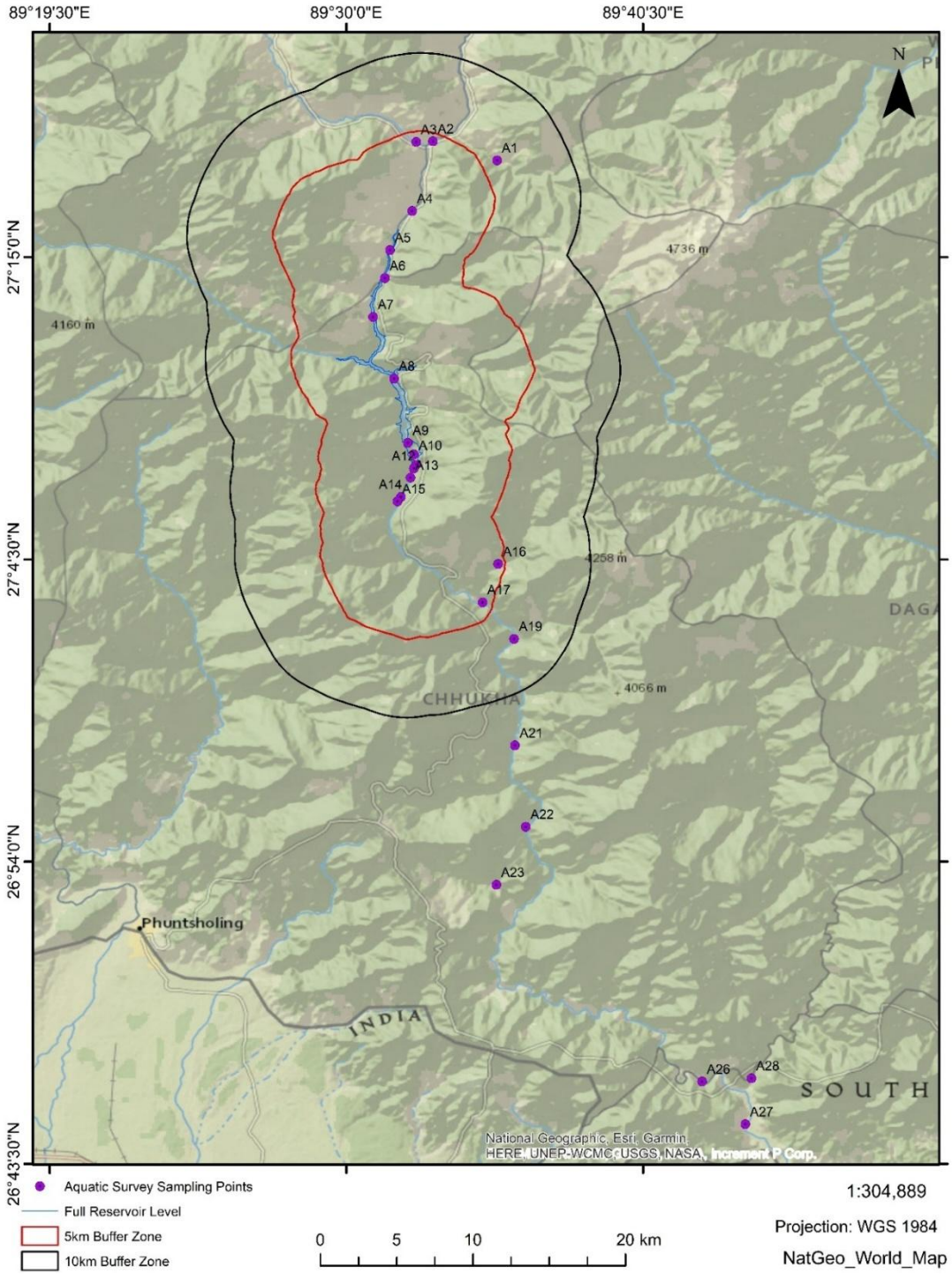


Figure 19: Aquatic biodiversity and water quality survey points (A#) within the Bunakha HPP's AoI

5.1.3.3 Survey procedures

5.1.3.3.1 Fish

Fish sampling followed the Department of Forest and Park Services' protocol (DoFPS, 2020). The sampling exercise was conducted across several-meter stretches (half of the stretch upstream and half of the stretch downstream of each of the sampling points), encompassing various habitat types, including pools, riffles and runs. A combination of fishing gear was employed, including a cast net, spinner hook, seine net, and electro-shocker, ensuring a strict catch-and-release method to minimize harm to the fish population. The data collected provided a basis for the calculation of catch per unit effort (CPUE) - see Chapter 5.1.3.4.

The fish species were identified following standard taxonomic regional and national literature and verified by Professor Dhan Bdr Gurung, an ichthyologist at the College of Natural Resources, Royal University of Bhutan.

Fish sampling - cast net method

The use of cast nets is a sustainable method for monitoring the fish population. The methodology was finalized based on DoFPS, 2020 and IFC, 2021.

A cast net measuring 6 feet, weighing 3–3.5 kg, with a 0.8×0.8 cm mesh was used, keeping a constant sampling duration of between 45 and 60 minutes (half of the time upstream + half of the time downstream) to complete 20 throws (in the 1st season), 80 throws (in the 2nd season), and 30 throws (in the 3rd season)[7]. At each sampling site, a 100 m stretch (in the 1st season) and a 400 m stretch (in the 2nd and 3rd seasons) were sampled (half of the stretch upstream + half of the stretch downstream). Water depth and velocity were recorded at each location.

Fish sampling - electrofishing method

The electrofishing sampling method was conducted based on DoFPS, 2020 and IFC, 2021.

Also in this method, 100 m stretches (in the 1st season) and 400 m stretches (in the 2nd and 3rd seasons) (half of the stretch upstream + half of the stretch downstream). One electroshocker was used, and two scoop nets were employed for fish collection, with a recommended mesh size of 0.5 × 0.5 cm. The sampling duration remained consistent, with 15-20 minutes allocated for upstream and 15-20 minutes for downstream sampling. Water temperature and conductivity were measured using a portable probe prior to sampling.

All necessary safety measures were strictly implemented during electrofishing, including the use of appropriate personal protective equipment (PPE) to minimize the risk of electric shock and ensure field safety. Additionally, the electrofishing team was trained in the safe handling and operation of the electroshocker, with one member designated to monitor equipment performance and ensure adherence to safety protocols throughout the sampling process.

[7] At certain sites, it was not possible to perform the full 80 throws due to accessibility challenges and site-specific conditions. In such cases, the number of throws was reduced accordingly. The method used at each site, along with the corresponding number of throws and the fish species captured, is presented in **Error! Reference source not found. Error! Reference source not found.**.

Fish sampling - seine net and spinner hook

Seine nets (measuring 5 meters in length and 1.5 meters in height; mesh size 0.5 cm) were employed as required, depending on site conditions, to collect supplementary data. Rock-flipping and kick-sampling were used to dislodge fish into the net in shallow riffles and runs.

Spinner hooks were also employed, particularly for sampling in deeper pool areas of the river where other methods were less effective. During the 1st season, spinner hooks were employed at 3 locations; during the 2nd and 3rd seasons, at 4 locations.

5.1.3.3.2 Macro-invertebrates

Sampling of macro-invertebrates followed the protocol of DoFPS, 2020 and used a multi-habitat sampling approach. Kick nets (25 cm × 25 cm frame with a 500 µm mesh) were placed perpendicular to the flow of water at the sampling sites (Figure 20). Boulders and cobbles larger than 5 cm were gently picked and rubbed to dislodge organisms into the net. The stream substrate was disturbed by hand or foot, and freshwater invertebrates were collected into the net. The net was then removed in a forward scooping motion, and the collected material was placed in a bucket. The net was thoroughly rinsed over the bucket with clean water. If the collected samples were turbid, they were diluted by adding clean water.

Sample specimens were identified and sorted into different groups in ice-cube trays. Individuals with the same morphotypes were counted and tallied in the datasheet. Photographs were taken for all taxa collected. Specimens that could not be identified in the field were collected in vials containing 70% ethanol along with labeled specimen codes. All other taxa were released back into the stream, except for those retained for laboratory assessment. All information was systematically recorded in the datasheet, covering all attributes in the form.

Figure 20: Macroinvertebrate sampling using a kick net (March 2025)

5.1.3.3.3 Periphyton

In each surveyed season, 5 hand-sized stones (with a maximum diameter/major axis of 15–25 cm) were sampled from slow-flowing areas that are year-round submerged and from locations undisturbed by benthic sampling. The stones were collected from a depth of 20–40 cm. To

minimize bias, the stones were selected without the collector looking into the water and were placed in a clean white tray.

Each stone was scrubbed separately in the tray using a brush to remove all periphyton and then rinsed with 100 ml of distilled water. The periphyton collected in the tray was transferred into a 250 ml sample bottle using a funnel. To preserve the samples, 2 ml of Lugol's iodine solution was added to each bottle. The bottles were labeled and stored in a dark bag for transportation to the laboratory for analysis. After sampling each stone, the tray, brush, and funnel were thoroughly rinsed with water to prevent contamination.

5.1.3.3.4 Phytoplankton

Phytoplankton samples were collected from each fish sampling site. At each site, a 10-liter composite sample was prepared by collecting 500 ml of water from 20 different microhabitats, including run, riffle, and pool habitats. Rocks and submerged plants present in each microhabitat were collected, and attached plankton was scrubbed off using a toothbrush. After thorough mixing, 250 ml of the composite sample was taken to the laboratory for taxonomic identification. To preserve the samples, 1% Lugol's solution was added.

5.1.3.3.5 Zooplankton

Zooplankton samples were collected from fish sampling sites. At each site, 200 liters of river water were collected from different microhabitats and filtered through a 64 µm plankton net made of Nitex nylon, with a 20 cm mouth diameter, 80 cm length, and a slotted cod-end assembly lined with Nitex nylon. The filtered sample collected at the cod-end assembly of the net was reduced to 100 ml, which was then taken to the laboratory for taxonomic identification. To preserve the zooplankton samples, a 5% formaldehyde solution was added.

5.1.3.3.6 Water quality

A total of 16 physicochemical water parameters were collected from the aquatic biodiversity sampling sites. Table 23 presents an overview of these parameters, together with the sampling method/instrument, volume, preservation method, storage conditions, and holding times.

8 parameters were measured onsite using equipment that was calibrated according to the respective manuals before the field surveys. The remaining 8 parameters were subject of laboratory analysis, for which collected samples were bottled and kept refrigerated. Each bottle was clearly labeled with the sample ID, collection date and time, preservative details, and the parameters to be analyzed. Samples were transported to the Soil Air and Water Testing (SWAT) laboratory, College of Natural Resources, Royal University of Bhutan, in a cooler with ice packs to maintain a temperature of approximately 4°C. Analyses were conducted within the recommended holding times.

Table 23: Physicochemical water parameters, sampling techniques, preservation methods, and holding times of the water quality survey undertaken during the three-seasons aquatic biodiversity surveys at the Bunakha HPP's AoI

Parameters	Method/ instrument	Sample volume	Preservation method	Storage conditions	Holding time (Max)
Temperature	PCS testr[8]	In situ	None	Measured onsite	Immediate
pH	PCS testr	In situ	None	Measured onsite	Immediate
Conductivity	PCS testr	In situ	None	Measured onsite	Immediate
TDS	PCS testr	In situ	None	Measured onsite	Immediate
Salinity	PCS testr	In situ	None	Measured onsite	Immediate
DO	YSI ProDSS	In situ	None	Measured onsite	Immediate
NH3	YSI ProDSS	In situ	None	Measured onsite	Immediate
Turbidity	YSI ProDSS[9]	In situ	None	Measured onsite	Immediate
TSS	Gravimetric laboratory analysis (PHA/Standard Methods 2540 D, EPA Method 160.2, and ASTM D5907)	500 mL	None	Refrigerated at 4°C	7 days
Chloride	Argentometric Titration (Standard Methods 4500-Cl)		None	Refrigerated at 4°C	28 days
Iron	Spectrophotometric analysis (ASTM D1068-10)	250 mL	Acidified with concentrated HNO_3 (pH < 2)	Refrigerated at 4°C	6 months
Ca	Complexometric titration (APHA Method 3500)		Acidified with concentrated HNO_3 (pH < 2)	Refrigerated at 4°C	6 months
Mg	Complexometric titration (ASTM D51)		Acidified with concentrated HNO_3 (pH < 2)	Refrigerated at 4°C	6 months

[8] Model: PCSTestr 35, often referred to as Eutech PCS Testr 35 or PCSTestr 35. Manufacturer: Eutech Instruments (Thermo Fisher Scientific)

[9] Model: ProDSS (Digital Sampling System) Multiparameter Handheld Meter. Manufacturer: YSI Inc. (a Xylem brand) Water Quality Meter

Parameters	Method/ instrument	Sample volume	Preservation method	Storage conditions	Holding time (Max)
TH	Calculated from Ca & Mg (APHA Method 3500-Ca) PHA Standard Methods: 3500-Mg B)		Acidified with concentrated HNO_3 (pH < 2)	Refrigerated at 4°C	6 months
P	Colorimetric or spectrophotometric analysis (APHA Method 4500-P)	250 mL	Preserved with concentrated H_2SO_4	Stored in dark, refrigerated	28 days
BOD	5-day incubation test (APHA/Standard Methods 5210 B)	500 mL	None	Refrigerated at 4°C	48 hours before analysis

5.1.3.3.7 Community knowledge survey on aquatic biodiversity

A structured questionnaire was used to capture local knowledge on aquatic biodiversity. Interviews were conducted individually, and information reliability was verified when responses were confirmed by three or more interviewees.

During the interviews, participants were provided with a map of the proposed development area and requested to indicate preferred habitats for specific species as well as sensitive areas within the AoI and the wider Ecologically Appropriate Area of Analysis (EAAA) - see Chapter 7.2.5.3.

5.1.3.4 Data analysis procedures

Aquatic biodiversity data was computed and analyzed using a Microsoft Excel spreadsheet. Descriptive statistics were obtained to compare the results of different sites.

5.1.3.4.1 Aquatic species analysis

Species diversity was determined based on the Shannon-diversity index (*H'*) (Equation 1), which provides the biotic density of the study site (richness) and the species' abundance distribution (Shannon & Weaver, 1949).

$$H' = -\sum_{i=1}^{n} pi * lnpi$$

Equation 1: Shannon Diversity Index

Where:

H'= Shannon Diversity Index
p_i= The proportion of individuals belonging to the ith species
ln= Natural logarithm function

The greater the Shannon Diversity Index, the greater the species diversity. The index usually ranges between 1.5 to 3.5 in most ecological studies; it can be less than 1.5 in some cases, and is rarely greater than 4.

Species evenness was computed using Pielou's Evenness Index (*J*) (Pielou, 1966) (Equation 2). J expresses how close the observed community is to perfect evenness, ranging from 0 to 1.

$$J' = \frac{H'}{\ln(S)}$$

Equation 2: Pielou's Eveness Index

Where:

J' = Pielou's Eveness Index
H '= Shannon Diversity Index
ln= Natural logarithm function
S = Species richness
ln (S) represents therefore the maximum possible diversity if all species were equally abundant.

The **catch per unit effort** (CPUE) for each method used (cast net, electroshocked, spinner hook) across each site was computed using Equation 3. The CPUE is a practical, indirect measure of the abundance of a fish population. It links how much fish is caught to how much effort was required, and is commonly used as a proxy for how many fish are in a population. When CPUE declines, it often signals that the stock is shrinking.

$$\text{Catch Per Unit Effort (CPUE)} = \frac{\text{Number of fish caught in site}}{\text{Number of efforts in site}}$$

Equation 3: Catch Per Unit Effort

Zooplankton and phytoplankton abundance were quantified using plankton concentrates prepared by filtering 500 mL of water from each site and concentrating it to 250 mL. Each concentrate was examined ten times under 10X magnification, while identification and enumeration were conducted under 40X magnification. Abundance values for both zooplankton and phytoplankton represent the mean of ten microscopic observations per sample, ensuring consistency, reliability, and comparability across sampling sites.

5.1.3.4.2 Natural and modified habitat identification

Freshwater habitat conditions were assessed using the Index Habitat Integrity (IHI) by Kleynhans, Cj, 1996. The IHI provides a tool for assessing integrity of instream and riparian habitat by using the set of criteria shown in Table 24.

Table 24: Criteria used for the assessment of habitat integrity (Kleynhans, Cj. 1996)

Instream channel criteria	Riparian zone criteria
Water abstraction	Bank erosion
Water quality	Indigenous vegetation removal
Bed modification	Water abstraction
Channel modification	Water quality
Flow modification	Channel modification

Instream channel criteria	Riparian zone criteria
Inundation	Exotic vegetation encroachment
Exotic macrophytes	Flow modification
Exotic fauna	Inundation
Solid waste disposal	

The severity of the impacts on river systems is classified based on six categories which comprise of ratings ranging from 0 to 25, where 0 means no impact (Table 25).

Specifically:

1 to 5 - small impact,
6 to 10 - moderate impact,
11 to 15 - large impact,
16 to 20 - serious impact, and
21 to 25 - critical impact.

Table 25: Descriptive classes for the assessment of modifications to habitat integrity used in the application of the IHI (adapted from Kleynhans, Cj., 1996)

Impact Category	Description	Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1 - 5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6 - 10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11 - 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16 - 20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21 - 25

The IHI method assigns percentage scores based on the degree of deviation of the habitat under assessment from natural conditions. These scores are grouped into six ecological categories describing the habitat integrity from Natural - Category A to Critically Modified - Category F (for example, a moderately modified habitat has a deviation of 60-79% of the natural conditions). The ESIA Team translated these categories into ADB SPS's Modified and Natural Habitat concepts (Table 26).

Table 26: Ecological categories, key colours, category descriptions (adapted from Kleynhans, Cj., 1996) and correlation with habitat categories as per ADB SPS/IFC PS 6

Ecological category		Description	Score (%)[10]	Natural / Modified Habitat as per ADB SPS / IFC PS6
A	Natural	Unmodified, natural.	90-100	Natural Habitat
B	Largely Natural	Few modifications, small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89	
C	Moderately Modified	A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79	
D	Largely Modified	Large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59	Natural / Modified Habitat

[10] % ranges are expert-defined thresholds by Kleynhans, Cj. to translate a river's condition into a standardized ecological category. Each disturbance factor (e.g., flow modification, sediment input, channel alteration) is rated for severity and extent. These ratings are weighted according to their ecological importance. The weighted scores are summed to produce an overall habitat integrity percentage. That percentage is then placed into one of the A–F categories.

Ecological category		Description	Score (%)[10]	Natural / Modified Habitat as per ADB SPS / IFC PS6
E	Seriously Modified	The losses of natural habitat, biota and basic ecosystem functions are extensive.	20-39	Modified Habitat
F	Critically Modified	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	<20	

5.1.4 Socio-economic survey methodology

The socio-economic survey was undertaken to establish a baseline understanding of the demographic, social, economic, and livelihood characteristics of communities within the Project Area of Influence. Survey respondents were selected from communities located within the direct and indirect area of influence of the proposed Project, including households potentially affected by project components and households representing broader community conditions.

Household selection considered geographic distribution, proximity to project infrastructure, land use characteristics, livelihood dependence, and potential exposure to project-related impacts. The survey was designed to capture a representative range of socio-economic conditions and stakeholder perspectives across the Project Area of Influence. In addition to household interviews, information was triangulated through focus group discussions, key informant interviews, field observations, secondary data review, and community consultations to improve the robustness of the baseline assessment.

The socio-economic survey was undertaken during the preliminary design stage of the Project. Consequently, some project components were subsequently refined during detailed engineering and ESIA preparation. To address this, additional verification of affected households, assets, and land requirements was undertaken through the Resettlement Plan preparation process and project-specific asset inventories.

The FGD and KIIs were carried out to capture diverse perspectives of the communities and the residents living there

For the FGDs a purposive selection of groups was made to ensure representation across gender, age, and livelihood categories. Around 6 - 8 participants were included in each group to allow for rich discussion while maintaining manageability.

Key informants were selected based on their knowledge, community roles, or direct involvement in community and institutional processes. This included local leaders, government officials and knowledgeable respondents.

Selection Procedure

For the FGDs, participants were identified through community representation and consultation with local representation (Tshogpa) to ensure inclusion of all groups.

For the KIIs informants were chosen using purposive sampling, targeting individuals with specialized knowledge or decision-making authority relevant to their knowledge of the community comprising of male, female, educated, business people aged and their representative of the aged.

This combination of FGDs and KIIs provided both collective community insights and individual expert perspectives.

FDG/KII with vulnerable Groups

Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were carried out with vulnerable group to ensure their perspectives were meaningfully captured. Participants were identified through the community and the local elected representative and the Ex-elected member, prioritizing groups such as women, old aged, most of whom were representatives or relatives. However, some old aged members did participate in the discussion. FGDs were conducted in safe, accessible locations with 6 - 8 participants per group, using participatory techniques to encourage open dialogue.

KIIs targeted individuals with specialized knowledge of community challenges, including local officials and religious leaders. Care was taken to build trust with respondent and ensure confidentiality, thereby creating an environment where vulnerable voices could be expressed freely and respectfully.

Primary socio-economic data was collected at the Bunakha direct AoI, specifically at the two Gewogs where several planned construction-related infrastructures are expected to be located:

- Chapcha-Bunakha, specifically the Bunakha Chiwog
- Geling-Chanachen, specifically the Chanachen Chiwog

The data collection was performed by conducting a socio-economic survey in April 23-29, 2025 at the households' level using a socio-economic questionnaire based on the Kobotool mobile application and simple random sampling techniques. The socio-economic survey covered a total of 61 persons from 23 households (HH), representing 31% of the total of 74 households resident in the surveyed area (47 HHs reside in Bunakha Chiwog and 27 HHs reside in Chanachen Chiwog) (Figure 21).

Figure 21: Selected images of the socio-economic survey within Bunakha HPP's AoI in April 2025. Left: Bunakha Chiwog. Right: Chanachen Chiwog

The socio-economic survey captured demographic, infrastructure, health, economic, livelihood income, expenditure and gender related aspects, allowing therefore the establishment of a robust baseline for the social impact assessment (further details in Annex 6). 7.311

Additionally, during the socio-economic survey, public consultation were performed with communities from Tsamdrak and Shemagangkha Chiwogs, allowing collection of views and concerns of affected people. At the time the survey was conducted, the exact locations of some infrastructures were not finalized and remained tentative. For example, the DGPC colony was initially proposed for Tshimalakha, and a stone quarry was proposed at Lobneykha. Due to this uncertainty, consultations were also carried out with communities in these villages to capture their perspectives (Figure 22).

Figure 22: Selected images of the consultations undertaken during the socio-economic survey within Bunakha HPP's AoI in April 2025. Left: Tshimalakha Chiwog. Right: Lobneykha Chiwog

The survey enumerators were trained on the usage of the survey questionnaire and mobile application prior to the mobilization to the field. Further details can be consulted in **Error! Reference source not found. Error! Reference source not found.**.

A range of qualitative information was collected, including:

- Community perceptions and attitudes toward the Project
- Anticipated benefits and potential adverse impacts
- Possible resettlement and displacement concerns
- Gender-specific issues affecting women and children
- Other locally relevant social and economic issues

Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were conducted to supplement household survey findings and obtain qualitative information regarding local livelihoods, land use practices, community infrastructure, cultural heritage, environmental concerns, development priorities, and perceptions regarding the proposed Project.

Participants included affected households and their family members, community members, women from affected areas, representatives of local institutions, local government officials, and other key stakeholders. Consultations were also undertaken with relevant district-level agencies, including the Dzongdag, Dzongrab, Dzongkhag Planning Officer, Dzongkhag Land Survey Office, District

Land Revenue Office, Divisional Forest Office, local government leaders, and representatives of local-level institutions.

Special attention was given to engaging potentially vulnerable groups and households, including women-headed households, elderly persons, economically vulnerable households, and other socially vulnerable community members. Where appropriate, consultations were conducted through targeted discussions and household-level interactions to facilitate meaningful participation and ensure that their concerns and perspectives were adequately captured.
Information obtained through the FGDs and KIIs was used to validate household survey findings, improve understanding of local social and environmental conditions, identify community concerns and priorities, and support the development of project mitigation and management measures.

5.2 Methodology for Specialist Studies

5.2.1 Environmental flow assessment

Figure 23 illustrates the E-flow assessment framework adopted for the Bunakha HPP. This is a structured, science-based approach to evaluating and manage the environmental flow in the Wangchhu River system.

The process begins with Scoping and Alignment, where project goals, stakeholder expectations, and regulatory contexts are clarified. This stage, which is now completed, is followed by Baseline Data Collection, which involves gathering hydrological, ecological, and socio-economic data to inform subsequent analyses.

Hydraulic Modeling (Desktop Reserve Model (DRM) within SPATSIM) is then employed to simulate flow regimes and assess habitat conditions under varying scenarios. The core analytical phase, E-flow Assessment & Analysis, integrates ecological requirements with hydrological data to define flow thresholds to support the area's ecosystem health. The framework also includes an evaluation of Cascade Cumulative Impacts, recognizing the interconnected nature of river systems and the potential for upstream-downstream effects.

To ensure long-term sustainability and responsiveness, an Adaptive Management Framework is incorporated, allowing for iterative adjustments based on monitoring and feedback. Finally, Reporting and Stakeholder Engagement are included to ensure transparency, facilitate knowledge exchange, and support collaborative decision-making.

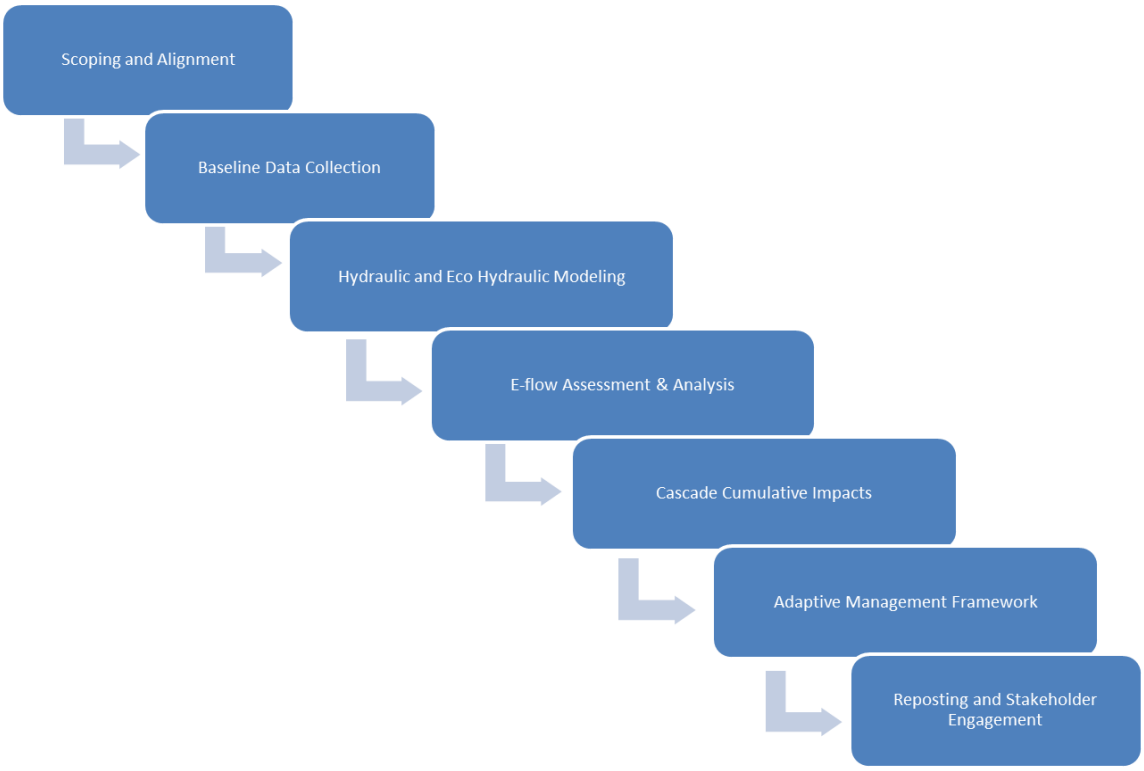


Figure 23: Methodology framework for the E-flow assessment for the Bunakha HPP

5.2.1.1 Scoping and alignment

The Environmental Flow (E-flow) assessment methodology presented during the Assignment's Inception Stage has been updated in response to the expanded scope of assessment and the comments received from ADB and the Department of Water (DoW) of Bhutan. The methodology integrates hydrological, hydraulic, ecological, and socio-cultural dimensions, ensuring alignment with the Bhutan Environmental Flow Guidelines (2019), ADB's Safeguard Policy Statement (2009), and ADB's Environmental and Social Framework (2024).

To achieve this, the team adopted a Decision Tree Approach (IFC, 2018) as the central guiding tool for determining the appropriate level of analytical resolution for each river segment. The decision tree allows systematic selection between different levels of analysis, ranging from desk-based hydrological review to full-scale hydraulic or eco-hydraulic modelling, based on the sensitivity, data availability, and management relevance of each reach. This structured approach ensures that the assessment focuses on where impacts are most significant, such as in regulated downstream reaches, while maintaining efficiency in less sensitive areas.

A critical refinement of the scope involved the adoption of a cascade-system perspective. While ecological connectivity does not extend across the downstream cascade due to regulated dams and reservoirs, the hydrological and operational interactions between Bunakha HPP, Chhukha HPP, and Tala HPP are explicitly analyzed. Bunakha HPP, as a regulating storage facility, has a significant influence on flow timing and volumes released downstream. These regulated releases interact with the operations of Chhukha and Tala.

Therefore, the E-flow assessment focuses on hydrological storage, flow modification patterns, operational scheduling, and associated socio-economic implications rather than direct ecological

continuity. This shift ensures that the cascade analysis remains relevant, technically robust, and aligned with the actual characteristics of the Wangchhu River system.

5.2.1.2 Baseline data collection

In line with the Bhutan Environmental Flow Guidelines (2019) and ADB safeguard requirements, comprehensive baseline data collection was/is being carried out to support the E-flow assessment.

- Hydrological data: Reference flows, in this case the flows at Bunakha Dam for the period 1976 to 2024
- Reservoir operation records from Bunakha (as foreseen in the ongoing Hydrology Report), Chhukha, and Tala HPPs are also being reviewed to capture regulated flow dynamics.
- Ecological surveys: Three season field surveys were undertaken. Critical habitats such as spawning grounds and riffle–pool complexes are mapped for the eco-hydraulic analysis. This allows linking hydraulic conditions with habitat suitability.
- Community water use: Household consultations documented water use practices for irrigation, domestic supply, and religious/cultural purposes. Traditional knowledge of seasonal flows and fish migration has been incorporated.
- Topographic and bathymetric data: Cross-sections and digital elevation models (DEMs) to define channel morphology.
- Secondary data: Relevant datasets from regulatory agencies,, and academic studies are being integrated to supplement field observations and fill data gaps.

5.2.1.3 Hydraulic modelling

Daily, monthly and annual discharge data of the Wangchu River at Bunakha were analysed to evaluate the hydrological characteristics and e-flow requirements of the river system. The available discharge records (1976 to 2024) indicated a mean annual flow (MAF) of 92.5 m^3/s. This data was used as the base hydrology for the Desktop Reserve Model (DRM) within SPATSIM to determine the e-flows. Baseflow (BF) separation was undertaken using the method as developed by Smaktin in 2001.

The modelling framework simulates river flow conditions and translates them into ecological and socio-economic implications. This process assesses how different operational scenarios influence habitat availability and community water use, and includes:

- Flow scenarios covering baseline (naturalized), current regulated, and Project-operational conditions.
- Eco-hydraulic metrics such as depth, velocity, wetted area, and shear stress under varying flows to evaluate habitat conditions.
- Habitat suitability modelling using species-specific indices for aquatic species identified during ecological surveys.
- Socio-economic relevance through comparison of hydraulic outputs with community water intake / use locations to determine impacts on access and timing of water availability.

5.2.1.4 E-flow assessment & analysis

This stage provides the technical basis for defining a flow regime that supports both hydropower operations and the needs of ecosystems and communities. It brings together hydrological

simulations, ecological response data, and socio-cultural factors into one flexible framework. The main components of the assessment include:

3. Identification of baseline and altered flow regimes based on long-term hydrological simulations, using outputs from the Project Hydrology Report.
1. Hydraulic modelling of cross-sections and critical reaches to establish relationships between discharge, depth, velocity, and wetted area.
2. Eco-hydraulic modelling to translate hydraulic conditions into habitat availability metrics for selected fish and aquatic invertebrate species.
3. Assessment of riparian and floodplain vegetation dependence on seasonal flow variability and inundation patterns.
4. Integration of socio-cultural data to determine implications for irrigation withdrawals, domestic water supply, and traditional uses.
5. Scenario-based evaluation of flow releases, comparing naturalized, regulated, and project-operational conditions to assess trade-offs. Alternative E-flow scenarios are generated and tested for habitat suitability, hydropower generation, and socio-economic trade-offs with scenario evaluation balancing ecological integrity and energy needs.
6. Application of adaptive management principles to refine flow recommendations based on field validation, monitoring, and stakeholder feedback.

The combined analysis results in the definition of recommended environmental flow regimes that are technically defensible, aligned with Bhutanese guidelines, and consistent with ADB safeguard requirements.

5.2.1.5 Cascade cumulative impacts

The Wangchhu River system is characterized by a series of hydropower plants operating in cascade, namely the future Bunakha dam and the existing Chhukha and Tala dams. To reflect the interconnected nature of the system, the cumulative analysis accounts for both Bunakha upstream and downstream influences. Although ecological connectivity is interrupted by the presence of reservoirs and dams, hydrological regulation and operational linkages significantly influence downstream flow regimes and socio-economic water uses.

Cumulative flow regulation impacts are assessed by integrating foreseen Bunakha (storage), Chhukha (run-of-river), and Tala (peaking) operational data. Reservoir operation scenarios are then linked to downstream flow alterations.

Upstream Influence of Bunakha

Bunakha HPP will play a critical role as a regulating storage facility in the cascade system. Its seasonal storage and release operations are planned to directly control inflows to Chhukha and Tala, thereby shaping the timing, magnitude, and variability of flows throughout the cascade.

Downstream Cascade Interactions

The downstream cascade, consisting of Chhukha and Tala HPPs, operates under flow regimes that will be influenced by future Bunakha releases. The E-flow assessment focuses on how reservoir operations alter discharge hydrographs, modify flow variability across seasons, and affect river segments downstream of the cascade. Specific emphasis is placed on:

a) Operational linkages between Bunakha, Chhukha, and Tala under varying hydrological conditions.
b) Impacts on flow variability and timing in dry and wet seasons.
c) Implications for downstream socio-economic water uses such as irrigation, domestic supply, and culturally significant practices.
d) Cumulative effects on sediment transport, channel morphology, and riparian vegetation due to flow regulation

By structuring the cascade analysis into upstream and downstream components, the assessment provides a comprehensive understanding of how storage, regulation, and operational interactions collectively influence flow regimes. This approach ensures that recommended environmental flows are grounded in the hydrological realities of the entire Wangchhu cascade system and are fully aligned with both ADB's and DoW's expectations.

5.2.1.6 Adaptive management framework

An adaptive management framework is developed, including proposals for real-time monitoring (hydrology and ecology), feedback mechanisms, and periodic revisions of flow releases to respond to new data or environmental changes.

5.2.1.7 Reporting and stakeholder engagement

This ESIA recommends that stakeholders including DoW, DGPC, regulators, and local communities are engaged through structured consultations. Validation workshops are recommended to be held to refine E-flow recommendations and build ownership.

5.2.2 Climate and Disaster Risk Assessment

A Climate and Disaster Risk Assessment (CDRA) is presented in Chapter 9.3, where the expected impacts of climate change on the Project are assessed. The CDRA applied a combined analytical approach using both historical observations and future climate projections to evaluate how climate change may affect the Bunakha HPP.

Historical hydro-meteorological data—precipitation, temperature, and streamflow—from stations across the Wangchhu basin were analyzed at seasonal and annual scale using the non-parametric Mann–Kendall trend test[11] to detect long-term changes. This was complemented by hydrological modeling using observed streamflow data to understand past and current water availability.

Future climate risks were assessed using CMIP6 (Coupled Intercomparison Project Phase 6) global climate model projections obtained from the World Bank's Climate Change Knowledge Portal. These projections were bias-corrected, downscaled, and analyzed across multiple future time horizons. The study used ensemble statistics—median, 10th, and 90th percentiles—to capture uncertainty. Projected changes in precipitation, temperature, extreme rainfall indices, and streamflow were integrated into SWAT (Soil and Water Assessment Tool), a hydrology and watershed-scale simulation model to estimate future water availability and potential impacts on floods, sediment load, and dam safety.

[11] The Mann–Kendall trend test is a non-parametric statistical method used to detect whether a time series—such as rainfall, temperature, or streamflow—shows a monotonic (consistently increasing or decreasing) trend over time.

The CDRA provides a structured basis for identifying climate risks and informing the project's Climate Risk Management Plan - available in Chapter 9.4.

5.2.3 Critical Habitat Screening

As part of the ESIA for the BHPP, a Critical Habitat Assessment (CHA) is performed. The CHA is preceded by a Critical Habitat Screening. The results of the Critical Habitat Screening and the CHA are presented in the ESIA Report (Chapter 7.2.5 and **Error! Reference source not found.**).

The methodology used for the Critical Habitat Screening is based on two core guidance documents, supplemented by the Consultant's experience and expertise: 1) ADB: Critical and Natural Habitat Screening for an ADB private sector project; and 2) IFC Guidance Notes on Performance Standard 6. The is shown schematically in Figure 24.

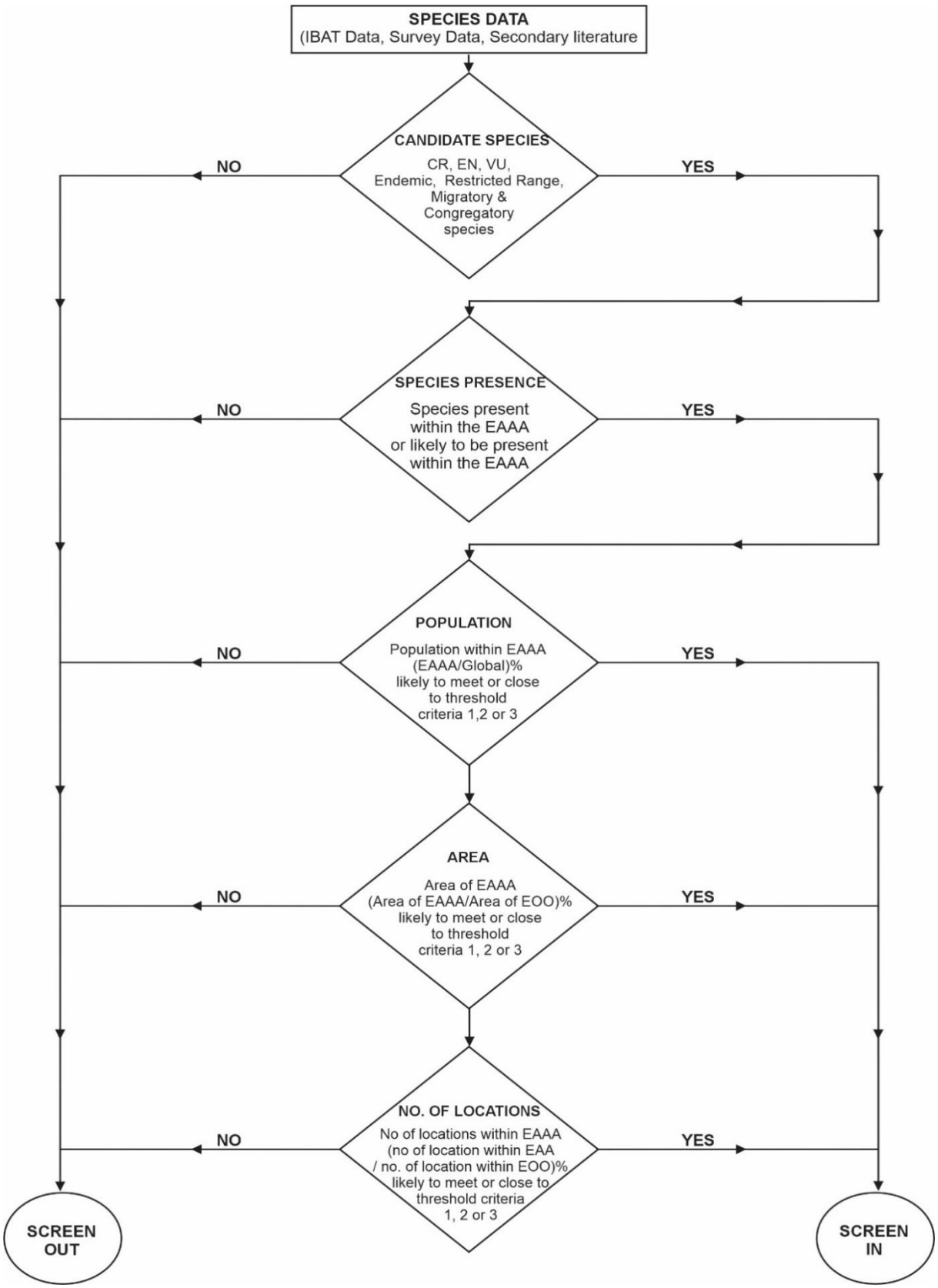


Figure 24: Schematic representation of the approach used for the Critical Habitat Screening for the Bunakha HPP

The first step of the Critcal Habitat Screening was to define the Project's Ecologically Appropriate Areas of Assessment / Analysis (EAAAs), which are the spatial areas that are ecologically relevant

for assessing the presence and viability of biodiversity features that may trigger critical habitat designation.

After identification of the EAAAs, a set of 6 critical habitat criteria was defined for the Bunakha HPP (Table 27):

- Criterion 1: Habitat required for the survival of critically endangered (CR) or endangered (EN) species
- Criterion 2: Areas having special significance for endemic or restricted-range species
- Criterion 3: Sites that are critical for the survival of migratory species. Areas supporting globally significant concentrations or numbers of individuals of congregatory species
- Criterion 4: Areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services
- Criterion 5: Areas having biodiversity of significant social, economic, or cultural importance to local communities
- Criterion 6: Areas either legally protected or officially proposed for protection, such as areas that meet the criteria of the World Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization's World Natural Heritage Sites.

Table 27: Critical habitat criteria and thresholds for the Bunakha HPP

CH Criteria	Threshold of the Criteria
Criterion 1: Habitat required for the survival of critically endangered (CR) or endangered (EN) species	(a) Areas that support globally important concentrations of an IUCN Red-listed EN or CR species (≥ 0.5% of the global population AND ≥ 5 reproductive units of a CR or EN species).
	(b) Areas that support globally important concentrations of an IUCN Red-listed Vulnerable (VU) species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds in (a).
	(c) As appropriate, areas containing important concentrations of a nationally or regionally listed EN or CR species.
Criterion 2: Areas having special significance for endemic or restricted-range species	(a) Areas that regularly hold ≥10% of the global population size and ≥10 reproductive units of a species.
Criterion 3: Sites that are critical for the survival of migratory species. Areas supporting globally significant concentrations or numbers of individuals of congregatory species	(a) Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle.
	(b) Areas that predictably support ≥10 percent of the global population of a species during periods of environmental stress.
Criterion 4: Areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services	No threshold value

CH Criteria	Threshold of the Criteria
Criterion 5: Areas having biodiversity of significant social, economic, or cultural importance to local communities	No threshold value
Criterion 6: Areas either legally protected or officially proposed for protection, such as areas that meet the criteria of the World Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization's World Natural Heritage Sites.	No threshold value According to IFC's Guidance Note on PS 6, Internationally and/or nationally recognized areas of high biodiversity value may require a critical habitat assessment. For example, ▪ Areas that meet the criteria of the IUCN's Protected Area Categories Ia, Ib and II. ▪ Key Biodiversity Areas (KBAs), which encompass Important Bird and Biodiversity Areas (IBAs).

The screening of candidate species is performed based all the six criteria.

Following the initial screening of 2,020 species, a total of 26 species were selected for further assessment (CHA).

5.2.4 Critical Habitat Assessment (CHA)

For further assessment, an EAAA boundary was delineated for each screened-in species, taking into account potential impacts and habitat connectivity. Within the EAAA boundary, the portion of a species' geographic range that is suitable for it to occupy was defined as the Area of Habitat (AOH). This AOH was used to assess whether the area meets the threshold criteria for Critical Habitat.

The assessments were conducted using population data. Where population data were unavailable, the AOH was used, and if neither population data nor AOH information was available, the number of locations of the species was utilized. Field data and consultations complement the analysis by providing a more comprehensive understanding of the species' population and distribution within the AOH.

Following the assessment, an initial draft of the CHA report was prepared. The CHA was undertaken consistent with the principles of IFC PS6 Critical Habitat assessment requirements. Expert consultations were subsequently conducted with Bhutanese forestry, biodiversity and ichthyology specialists, and based on their input, the final draft of the Critical Habitat Assessment report was prepared. This report is available in **Error! Reference source not found.**

A schematic representation of approach for the CH assessment is represented in Figure 25.

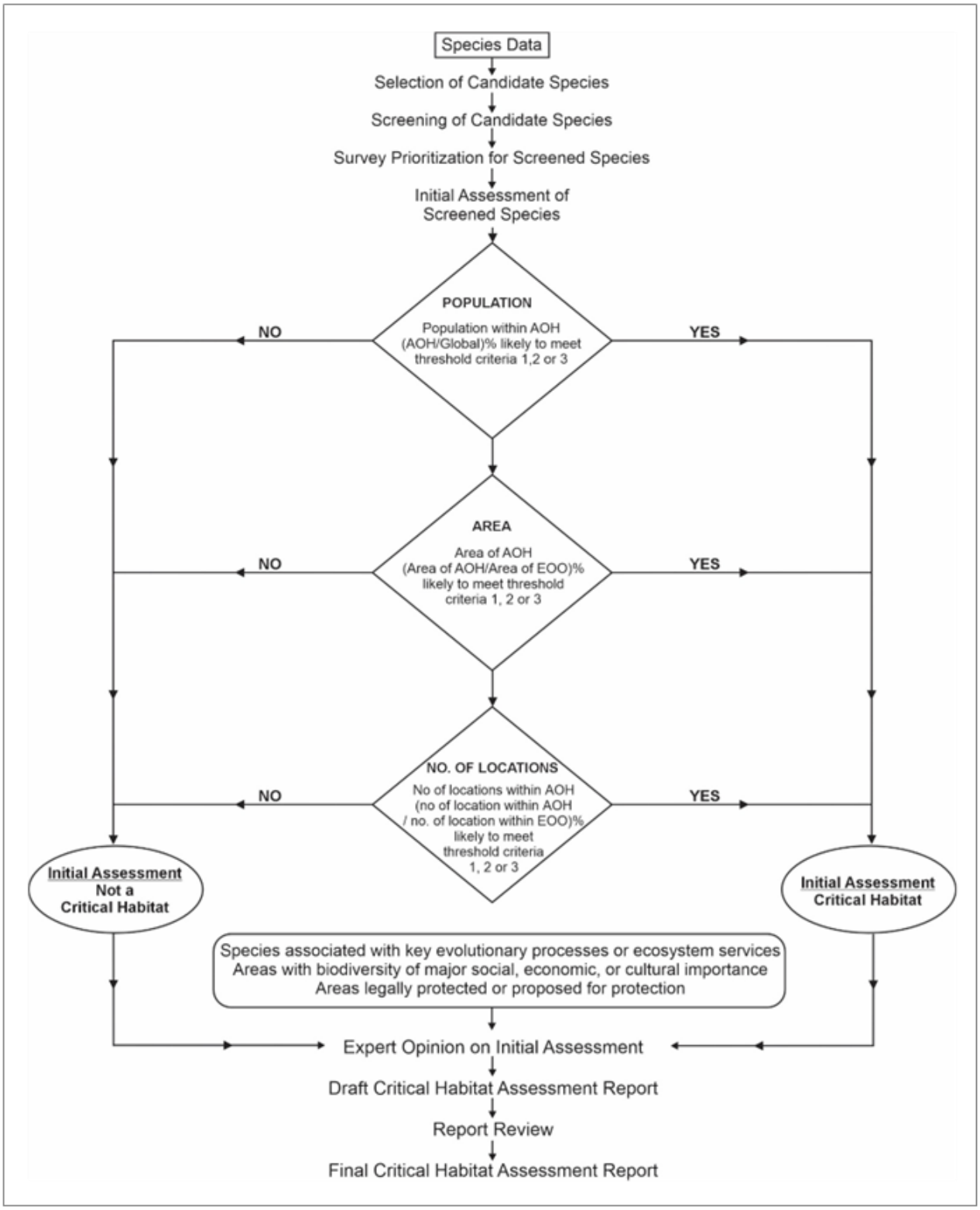


Figure 25: Schematic representation of the approach used for the CHA for the Bunakha HPP

5.2.5 Resettlement plan

The Resettlement Plan (RP), available in Annex 9, was developed as a comprehensive assessment, inclusive of the communities' views. This was achieved through organizing meetings with local leadership, government institutions and local communities, as well as interviews and questionnaire administration to the APs and other Interested and Affected Parties (IAPs).

The social assessment undertaken for the Bunakha HPP included two complementary activities: (i) a census and inventory of losses of all identified project affected households within the confirmed Project impact area; and (ii) a broader socio-economic survey undertaken to establish baseline socio-economic conditions within the Project area of influence.

The resettlement census and inventory of losses covered all currently identified affected households and affected persons associated with confirmed permanent Project impacts. The census collected information on household composition, affected land and assets, livelihood characteristics, and potential resettlement impacts in accordance with ADB SPS (2009) requirements.

5.2.5.1 Resettlement census survey

A census survey covering 100% of the households potentially affected with economical and/or physical resettlement (30 directly affected households[12]) was conducted in August 2025 guided by the requirements of ADB SPS (2009).

The resettlement census surveyors applied a semi-structured questionnaire based on the Kobotool mobile application - see Annexes 9 (separately provided). The resettlement census survey was administered based on the design drawings available at the time, ensuring that all potentially directly impacted households were included. Through this process, data was collected on:

- Household composition, including the number and demographics of family members
- Primary sources of income and average annual earnings
- Educational attainment of household members
- Vulnerability status, including indicators such as poverty, disability, old age, or female-headed households

This information was gathered directly from the affected households and their family members through face-to-face interviews.

Furthermore, tailored consultations were carried out with key stakeholders to ensure inclusive participation and transparency. These stakeholders included:

- Family members of households likely to be directly affected by the Project
- Local key informants

The resettlement census survey provided the basis for preparation of the Resettlement Plan, available in Annex 9.

[12] Please consult the Glossary of Terms for the definition of the different categories of affected people used in this report

5.2.5.2 Inventory of losses

To obtain information of the assets to be affected by the Project, an inventory of losses was made covering 100% of the affected assets such as land, structures, trees, crops and public infrastructure, including community assets.

The inventory, prepared by the RP and DPR teams, local community and directly affected households, contains the name of household's head, address, and types of owned structure.

5.3 Methodology for Assessment of the Significance of Impacts

Due to the fact that there is no official international consensus on an agreed approach for assessing the significance of impacts on the environment and the communities within a project's area of influence, the Consultant developed an own evaluation procedure. This procedure is based upon the Consultant's extensive experience in performing Environmental and Social Impact Assessments.

The methodology used in this ESIA study for classifying the É&S impacts of the project is based primarily on the ARVI approach (IMPERIA, 2015). ARVI is an approach for assessing the significance of the expected impacts of a proposed development project and was the key deliverable of the EU sponsored IMPERIA Project[13].

The ARVI approach was adapted by the Consultant based on the European Commissions' Guidance on Scoping (EU, 2017) and their long-term experience with ESIAs. This resulted in a transparent, reliable and objective methodology that is depicted into the following 3 steps:

- Step 1: Distinguish positive and negative impacts
- Step 2: Dismiss non-significant impacts
- Step 3: Multi-criteria analysis for significant impacts pre- and post-mitigation

A scheme of the three steps and the interactions among them is shown in Figure 26. An explanation is provided in the following paragraphs.

[13] More on this project here: https://www.jyu.fi/science/en/bioenv/research/natural-resources-and-environment/imperia-project

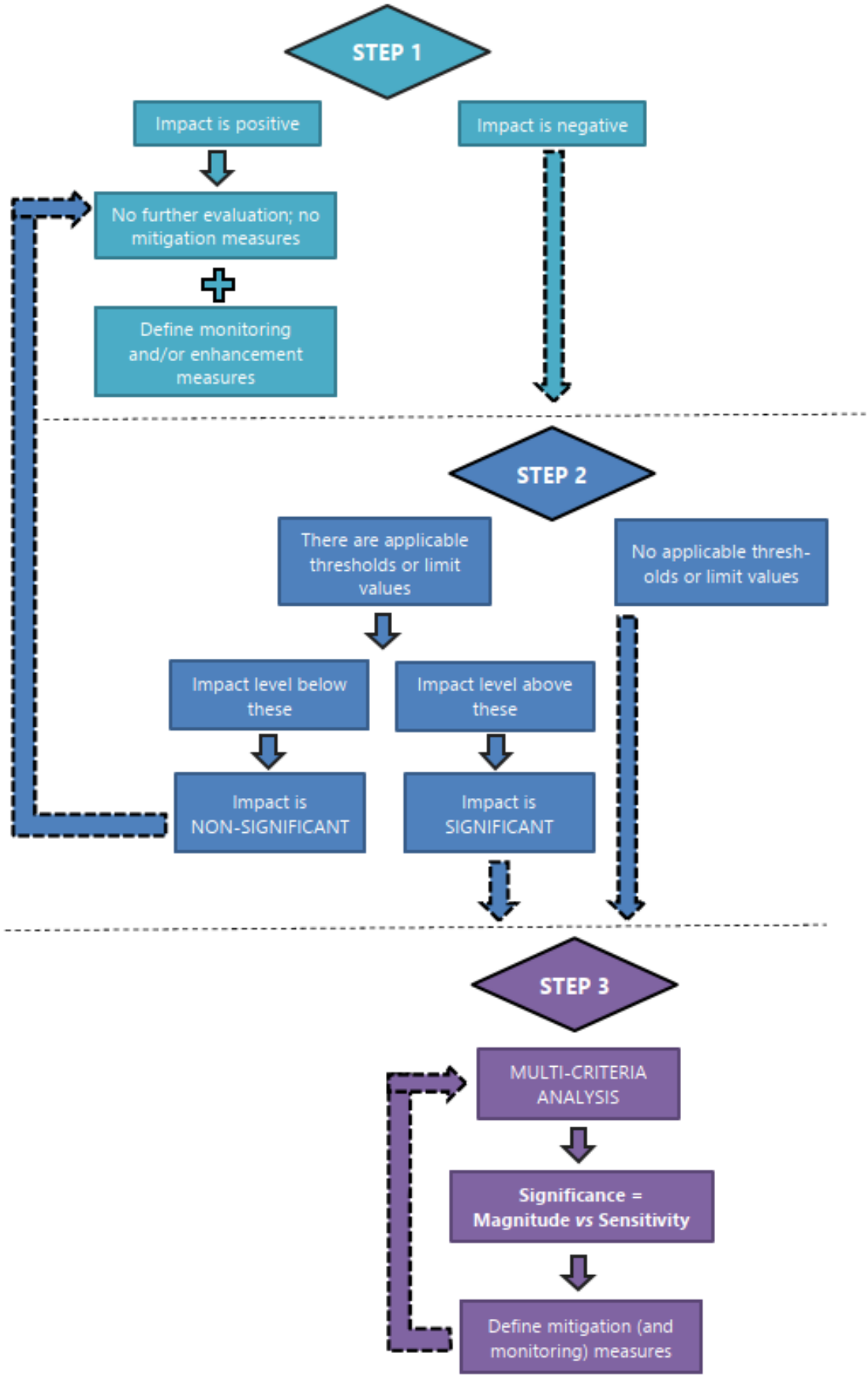


Figure 26: The Consultant's methodology for assessment of the significance of impacts

Step 1: Distinguish positive and negative impacts

The methodology begins by distinguishing positive from negative impacts. **Positive** impacts do not require further evaluation but require the development of enhancement and respective monitoring measures where pertinent and feasible.

Enhancement measures for positive impacts can be described as deliberate actions to strengthen, amplify, or extend the beneficial effects of a project. While mitigation measures aim to reduce negative impacts, enhancement measures focus on maximizing the project's positive environmental, social, or economic outcomes beyond what would occur naturally.

Negative impacts shall be further evaluated in Step 2.

Step 2: Dismiss non-significant impacts

For those impacted components for which a threshold or a limit value is defined (in the national legislation or international guidelines), these shall be used to initially understand the degree of change in the receiving environment. If the impact of the project is foreseen as being below the threshold or limit value, then the impact can be classified as **non-significant** and can be dismissed from further assessment. For non-significant impacts mitigation measures are not necessary, but monitoring may be

If the impact of the project is foreseen as being above the threshold or limit value, then the impact can be classified as **significant** and shall be subject of further assessment by using the multi-criteria analysis method (Step 3). This method is also to be used when no thresholds or limit values are available.

Step 3: Multi-criteria analysis for significant impacts pre- and post-mitigation

At present, there is no international consensus among practitioners on a single or common approach for analysing and classifying the significant impacts. This report adopted the one commonly followed in the EU that consists of evaluating significance based on the magnitude of the predicted effect and the sensitivity of the receiving environment:

Magnitude vs Sensitivity = Significance

The formula above is applied exclusively to negative significant impacts, i.e., to those impacts that need further assessment beyond steps 1 and 2.

For all significant impacts, mitigation measures are defined to lower, eliminate or compensate for negative effects. The residual significance, i.e., the significance after specified measures are applied is then assessed by applying once more the multi-criteria analysis.

5.3.1 Sensitivity

The sensitivity of the receiving environment can be measured based on 3 criteria, each of them being evaluated based on 4 levels.

- Existing regulations and guidance - there are specific receptors[14] in the impact area which have some level of protection, either by law or other regulations:
  - very high protection level - the impact area includes an object that is protected by national law or international agreements which may prevent the proposed development
  - high protection level - the impact area includes an object that is protected by national law or international agreements which may impact the feasibility of the proposed development
  - medium protection level - national regulation sets recommendations or reference values for an object in the impact area, or the project may impact an area conserved by a national or international program
  - low protection level - few or no recommendations which add to the conservation value of the impact area, and no regulation restricting use of the area (e.g., zoning plans)
- Value of the receptor to the society - economic values, e.g. water supply; social values, e.g. landscape or recreation; or environmental values, e.g. natural habitat:
  - very high - the receptor is very unique, very valuable to society and possibly irreplaceable; it may be deemed internationally significant and valuable; the number of people living within, depending on or using the area in any other way is very large
  - high - the receptor is unique and valuable to society; it may be deemed nationally significant and valuable; the number of people living within, depending on or using the area in any other way is large
  - medium - the receptor is valuable and locally significant but not very unique; the number of people living within, depending on or using the area in any other way is moderate;
  - low - the receptor is of small value or uniqueness; the number of people living within, depending on or using the area in any other way is small.
- Vulnerability to the changes brought up by the project under evaluation (ability to tolerate changes; number of sensitive targets):
  - very high - Even a very small external change could substantially change the status of the receptor. There are many sensitive targets in the area.
  - high - Even a small external change could substantially change the status of the receptor. There are many sensitive targets in the area.
  - medium - At least moderate changes are needed to substantially change the status of the receptor. There are some sensitive targets in the area.
  - low - Even a large external change would not have substantial impact on the status of the receptor. There are only few or no sensitive targets in the area.

After each sensitivity criteria is classified according to one of the 4 levels, these are evaluated by means of a scoring system, improving thereof the level of transparency and objectivity of the analysis. The result is a classification of the sensitivity of each impact as low, medium, high, and very high.

[14] Receptors are: population and human health, biodiversity, land, soil, water, air and climate, material assets, cultural heritage, and the landscape

SENSITIVITY					Example
Scoring Criteria	1:	2:	3:	4:	Receptor X
Existing regulations and guidance	Low protection level	Medium protection level	High protection level	Very high protection level	*Very high: 4*
Value of the receptor	Low	Medium	High	Very high	*High: 3*
Vulnerability to the changes	Low	Medium	High	Very high	*Low: 1*
Sum					***8***
Sensitivity of the receptor					***Medium***

Key:

Sensitivity	Sum
Low	3 to 5
Medium	6 to 8
High	9 to 10
Very high	11 to 12

5.3.2 Magnitude

The magnitude of the negative significant impacts is evaluated based on 6 criteria, each of them being evaluated based on 2 to 4 levels:

- Spatial extent of the impact
  - local: up to 5 km (typically including site + neighbouring properties/settlements)
  - municipal: 5 -10 km (typically including one municipality)
  - regional: 10 - 100 km (typically including one region)
  - wide range/transboundary: > 100 km (typically including several regions and/or crossing national borders)[15]
- Duration of the impact (length of time during which the activity that delivers an impact is observable)
  - short term: construction activity16 <1 year
  - medium term: construction activity >1 year
  - long term: project life (operation)
  - permanent: lasting (even after decommissioning)
- Frequency of the impact
  - once / occasionally or never (for example, after mitigation)
  - irregular but less than or equal to once per year
  - seasonal (2 to 4 times per year)
  - repeatedly (more frequently than 4 times per year)
- Reversibility of the impact:
  - reversible impact

[15] A transboundary impact is always classified as a wide range impact, even when it is expected within a range shorter than 100 km
[16] Construction activity in this context refers to specific time-limited activities leading to impacts such as excavations, levelling, blasting, etc., and not to the whole construction period.

- irreversible impact
- Probability of the impact occurring (expert assessment)
  - unlikely: unlikely to occur
  - possible: may occur
  - probable: likely to occur
  - definite: will certainly occur
- Intensity of the impact (can often be measured with various physical units; if not, expert assessment is used)
  - low - the change to environmental conditions or on people is small (or between 0% and 15% above thresholds/standards)
  - medium - the project has a clearly observable negative effect on nature or environmental load (or between 15% and 25% above thresholds/standards). A social change has an observable effect on people's daily lives and may impact daily routines.
  - high - the project has a large detrimental effect on nature or environmental load (or between 50% and 75% above thresholds/standards). A social change clearly hinders people's daily lives.
  - very high - the project has an extremely harmful effect on nature or environmental load (or equal to or more than 75% above thresholds/standards). A social change substantially hinders people's daily lives.

For social impacts, the assessment of magnitude was informed by a combination of: (i) socio-economic survey data; (ii) focus group discussions (FGDs), key informant interviews (KIIs), and public consultations undertaken during stakeholder engagement activities; and (iii) professional judgement of the ESIA team. Stakeholder perceptions and concerns recorded through consultations were used to validate the significance, extent, duration, and reversibility of potential impacts and to identify community-specific sensitivities that may not be captured through quantitative survey data alone.

After each magnitude criteria is classified according to one of the 4 levels (or 2 levels, in case of "reversibility"), these are evaluated by means of a scoring system, thereby improving the level of transparency and objectivity of the analysis. The result is a classification of the magnitude of each impact as low, medium, high, or very high.

MAGNITUDE					Example
Scoring Criteria	1:	2:	3:	4:	Impact X
Spatial extent	Local	Municipal	Regional	Wide range/ Transboundary	*Municipal: 2*
Duration	Short term	Medium term	Long term	Permanent	*Permanent: 4*
Frequency	Once/ occasionally or Never	Irregular	Seasonal	Repeatedly	*Once: 1*
Reversibility	Reversible	-	-	Irreversible	*Reversible: 1*
Probability	Unlikely	Possible	Probable	Definite	*Possible: 2*
Intensity	Low	Medium	High	Very high	*Medium: 2*
Sum					***12***

Magnitude of the impact	***Medium***

Key:

Magnitude	Sum
Low	6 to 9
Medium	10 to 14
High	15 to 19
Very high	20 to 24

5.3.3 Significance

The level of significance of each impact is finally assessed as low, medium, high, or very high. This is done by means of a **significance matrix** evaluating the magnitude of the impact against the sensitivity of the receiving environment.

SIGNIFICANCE		Magnitude of the impact			
		Very high	*High*	*Medium*	*Low*
Sensitivity of the receptor	*Low*	High	Medium	Low	Low
	Medium	High	High	Medium	Low
	High	Very high	High	High	Medium
	Very high	Very high	Very high	High	High

5.3.4 Assessment of cumulative impacts

The cumulative impact of the Project is the incremental impact of the Project when added to impacts from other relevant past, present and reasonably foreseeable developments as well as unplanned but predictable activities enabled by the project that may occur later or at a different location (WB, 2016).

The possibility for cumulative impacts is determined within the present ESIA to the extent that information on past, present and reasonably foreseeable developments is available. However, the assessment of the significance of cumulative impacts using the methodology as described previously in this report may not be possible. This is justified with experience with assessment of the significance of cumulative impacts that shows that application of significance determination methods normally used in ESIA is very difficult (IFC, 2013).

For any potential cumulative impact identified, and independently on whether its significance may be assessed or not, additional mitigation and/or monitoring beyond that identified for non-cumulative impacts will be considered.

6 Analysis of Alternatives

6.1 Location Selection

The BHPP is located in Bunakha village, Chhuka Dzongkhag district, Western Bhutan. The project site was strategically selected due to its favourable accessibility, situated 3.25 km upstream of the existing Chuka dam along the Phuentsholing-Thimphu highway. In early studies, the dam location was identified after carrying out detailed geotechnical investigations at multiple locations along the river. The dam location adopted in the original THDC study was kept unchanged in the Updated Detailed Project Report (UDPR) submitted in November 2025. However, in the present revised layout, the dam axis has been shifted approximately 65 m upstream of the previously proposed location. This change was made because the upstream location offers better rock conditions, avoids a zone of slope movement on the left bank, and helps reduce the amount of excavation and foundation treatment required. Regarding the powerhouse, earlier studies including the THDC study and the November 2025 UDPR proposed a surface powerhouse at the toe of the dam. Following detailed discussions, financial analysis, and recommendations from the Panel of Experts, the concept was revised to adopt an underground powerhouse arrangement. The portal of the main access tunnel to the powerhouse is now located approximately 400 m downstream of the toe of the current dam location.

6.2 Description of the Initial Options

Two layout configurations have been studied by the Consultant for the BHPP. The first is the option presented in the Updated Detailed Project Report (UDPR) submitted in November 2025, and the second is the present revised layout developed following further engineering assessments and recommendations from the Panel of Experts (PoE). Both options retain the same key project parameters including a dam height of 205 m, a Full Reservoir Level (FRL) of 2006 masl, a Minimum Draw Down Level (MDDL) of 1950 masl, and an installed capacity of 180 MW comprising three units of 60 MW each. The primary differences between the two options relate to the dam axis alignment, dam geometry, spillway location, powerhouse arrangement, river diversion approach, and associated downstream structures.

November 2025 UDPR Layout

The baseline hydropower configuration consisted of a straight-axis RCC gravity dam with a kinked alignment, a crest elevation of 2010 masl, a crest length of 500 m, a four-bay spillway on the left bank, and a surface powerhouse at the dam toe. River diversion required two long external tunnels (9.5 m internal diameter) on the right bank, and a downstream Counter Barrage was proposed to raise the plunge pool water level to limit scour near the sensitive left-bank Nala area.

E&S and Technical Drawbacks: Detailed geotechnical investigations later revealed that the left-bank spillway required deep excavations directly within or near an active slope movement zone. This posed a critical threat to long-term structural safety, risking landslide-induced structural failure and severe siltation. The surface powerhouse was heavily exposed to hydraulic hazards and the external diversion tunnels introduced high construction footprint risks in variable geology.

While this configuration was considered technically viable at the time of the UDPR, subsequent assessments identified slope instability concerns on the left bank. The area accommodating the

spillway and associated structures was found to be within or in close proximity to a zone of active slope movement, raising concerns about the long-term safety and stability of critical dam structures in that zone. See Figure 27.

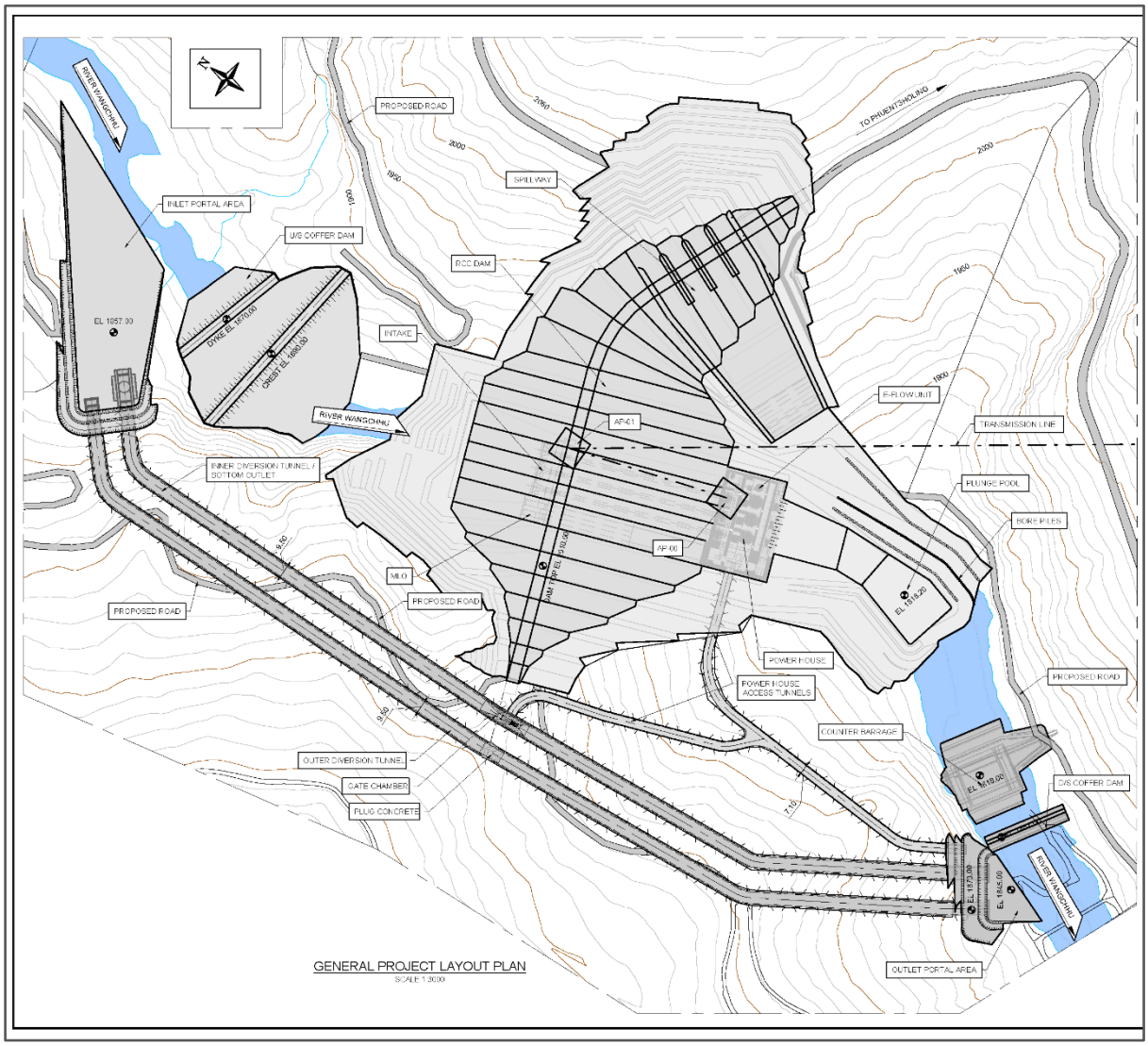


Figure 27: General layout of project components as per UDPR (Nov, 2025)

Revised Present Layout (Feb, 2026)

Based on further engineering studies, financial analysis, and recommendations from the Panel of Experts, a revised layout has been developed that introduces several important changes while retaining the same dam height, reservoir levels, and installed capacity.

The final layout features a curved gravity RCC dam with the axis shifted 65 m upstream of the original location. The crest length is reduced to ~430 m (crest elevation 2010 masl), and the foundation is taken down to 1800 masl into competent rock formations. The spillway remains centrally positioned. Crucially, the surface powerhouse is replaced with an underground powerhouse cavern system on the right bank, with its main access tunnel portal located 400 m downstream. Additionally, external diversion tunnels are replaced by an in-dam culvert diversion system.

- Geotechnical Risk Elimination: The 65 m upstream shift places the dam on uniform, high-bearing-capacity rock formations, completely bypassing the active landslide zone on the left bank.
- Habitat and Asset Protection: Relocating the powerhouse underground isolates critical energy infrastructure from surface hazards (flooding, debris flows, landslides). The downstream plunge pool shifts away from the sensitive left-bank Nala area, eliminating the need for a Counter Barrage and minimizing downstream riverbed disruption.
- Reduced Material Footprint: The arc geometry utilizes the valley abutments to distribute hydrostatic loads, significantly reducing the required volume of Roller Compacted Concrete (RCC) and its associated processing and transport emissions.
- Streamlined Construction Impacts: The in-dam culvert diversion confines river diversion within the permanent dam footprint, avoiding the heavy terrestrial disturbance and muck disposal impacts associated with long external diversion tunnels. This allows underground powerhouse excavation to proceed in parallel, optimizing the construction timeline.

As a result of the underground powerhouse arrangement and the upstream shift of the dam and plunge pool, the Counter Barrage proposed in the UDPR layout is no longer required in the revised configuration. The powerhouse is no longer directly exposed to spillway discharge, the plunge pool has moved away from the sensitive left-bank Nala area, and the revised geological profile reduces the risk of underscoring beneath the dam. (See Figure 28).

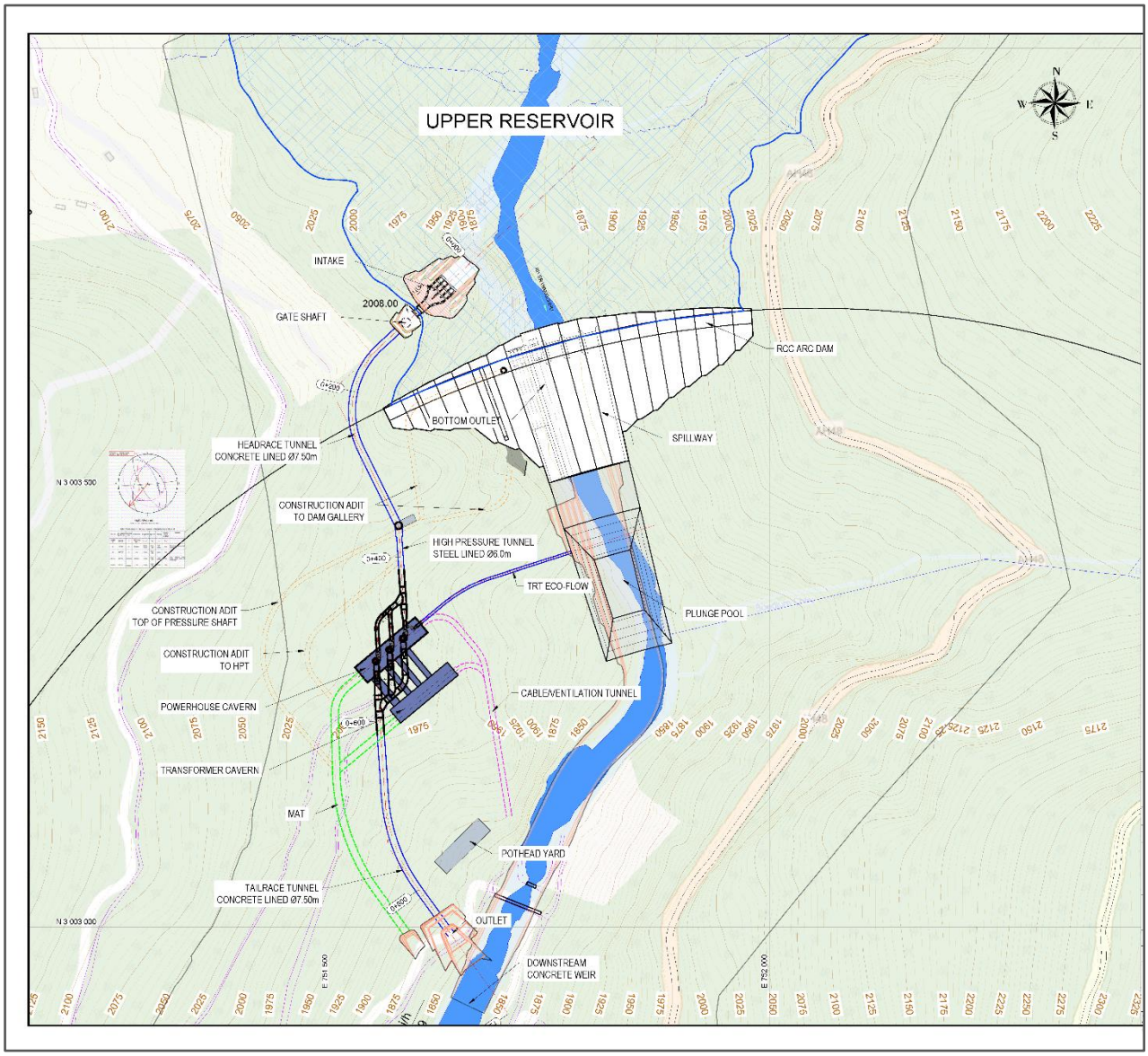


Figure 28: General layout of project components (As per revised concept)

Comparative Summary

The revised layout comprehensively addresses the technical, geological, and safety concerns identified in the November 2025 UDPR option. The adoption of a curved gravity dam with a reduced crest length, centralization of the spillway, transition to an underground powerhouse, simplification of the river diversion arrangement, and elimination of the Counter Barrage together result in a safer, more structurally efficient, and more economical project configuration. These refinements were guided by detailed site assessments and expert recommendations, and collectively represent a more robust and sustainable design for the Bunakha HPP.

6.3 Analysis of Technologies and Design

The BHPP adopts a Roller Compacted Concrete (RCC) arc gravity dam with a curved axis configuration. RCC technology was selected because it allows a shorter construction period, requires lower cement content compared to conventional concrete, and follows a well-established construction methodology used worldwide. These features help reduce both the overall construction schedule and the carbon footprint of the dam. The revised project layout has also

reduced the crest length from 500 m in the earlier option to 430 m, which further decreases material requirements and minimises land disturbance.

The powerhouse has been planned as an underground facility, with the major generating components placed within the rock mass. This arrangement significantly reduces surface disturbance near the dam toe, limits vegetation clearing, and avoids major visual impacts on the surrounding landscape. The underground configuration also improves the plant's resilience against floods and landslide-related hazards.

The electromechanical system consists of three vertical-shaft Francis turbines, each with a capacity of 60 MW. Francis turbines are the most suitable and widely accepted technology for the proposed head range. The turbines are expected to achieve an efficiency of about 94.5%, while the generators are designed for approximately 98.5% efficiency, ensuring maximum electricity generation from the available water resource. Plant operation and monitoring will be carried out through a SCADA-based supervisory control system with microprocessor-based automatic sequence control for each generating unit. This enables reliable automated operation, centralized control, and accurate energy metering.

The bottom outlet has been designed to provides sediment flushing capability for long-term reservoir management. To ensure dam safety, the project includes a comprehensive instrumentation system consisting of pendulums, piezometers, joint meters, thermocouples, and drainage gauges. These instruments will be connected to a centralized data acquisition system for continuous structural monitoring and performance assessment.
The alternatives assessment also considered the use of existing transportation infrastructure to the maximum extent practicable. The Project will primarily utilize existing national and local road networks, thereby minimizing the need for new access roads and reducing potential land acquisition, physical displacement, livelihood disruption, forest clearance, and habitat fragmentation associated with linear infrastructure development.

6.4 Consideration of Environmental and Social Factors in Alternative Selection

The evaluation of alternatives for the Bunakha HPP considered not only technical and economic feasibility but also environmental and social factors. During the review and update of the Detailed Project Report (DPR), efforts were made to minimize adverse impacts on communities, private land, livelihoods, and environmentally sensitive areas while maintaining the Project's technical and operational objectives.

Particular consideration was given to reducing the extent of land acquisition and associated displacement through optimization of the location and design of permanent project components, contractors' construction facilities, camp area, access roads, muck disposal areas, and ancillary infrastructures. Wherever practicable, preference was given to the use of state reserved forest land and locations with lower concentrations of residential structures and productive assets.

The alternatives assessment also considered potential impacts on local communities, including effects on agricultural land, access routes, community infrastructure, and livelihood activities. Environmental and social information collected during field surveys, stakeholder consultations, and socio-economic assessments informed the refinement of project layouts and the selection of preferred alternatives.

As a result, the preferred project configuration represents a balance between engineering feasibility, economic viability, environmental protection, and social impact minimization. Residual impacts that could not be avoided through design optimization have been addressed through mitigation measures, compensation provisions, livelihood restoration measures, and environmental and social management plans presented in this ESIA and the accompanying Resettlement Plan.

6.5 “Without Project” Situation

In the absence of the BHPP, the substantial hydropower potential of the Wangchhu River in western Bhutan would remain unharnessed, and the region would continue to forgo a significant and reliable source of clean electricity. The 180 MW of installed capacity that the project would contribute to the grid would instead need to be met through alternative means, likely involving greater reliance on electricity imports, both of which carry higher carbon intensities and economic costs. The existing Chhukha dam, located 3.25 km downstream, would continue to operate in isolation without the upstream storage and flow regulation that Bunakha's reservoir would provide, thereby limiting the operational efficiency and energy optimization of the river cascade as a whole.

From a socioeconomic standpoint, the absence of the project would mean the loss of construction-phase employment, infrastructure development in the Chhukha Dzongkhag area, and long-term revenue generation from power exports that are central to Bhutan's development financing. In summary, the "without project" scenario represents a missed opportunity to advance Bhutan's clean energy goals, regional energy security, and climate commitments under a technically sound and geologically well-sited configuration.

Multi-Criteria Analysis (MCA) Matrix

The matrix below systematically contrasts the performance of each alternative across the core selection criteria.

Project Alternatives	Capacity (MW)	Cost (CAPEX / OPEX)	Asset Lifetime	Impacted HHs	Dam Failure / Slope Risk Footprint	Biodiversity Impacts
No project Scenario	0	-	0	None	None	None (Baseline River corridor preserved)
November 2025 UDPR Layout	180	CAPEX- 67,672 MNu OPEX – 676.72 MNu (1st Year)	≥35 years	30 HHs	High Risk (Active slope movement on left bank threatens structures)	high scour/erosion risk at sensitive left-bank Nala
Revised Present Layout (Feb, 2026)	180	CAPEX- 58,530 MNu OPEX – 495.50 MNu (1st year)	≥35 years	30 HHs	Minimal Risk (Bypasses landslide zone; underground asset isolation)	(Protects Nala; eliminates Counter Barrage & external tunnels)

No alternatives to hydropower were considered for this project as a large consideration of this project was to ensure a stable all year round water supply for the local community and the community further downstream. Alternative sources of energy producing technologies would not be able to address this concern and thus were never considered. Alternative considerations for this project focused on minimizing the impact and elevating the positive impacts as described in the section above.

7 Description of the Existing Environment

This section provides a description of the Project-relevant environmental and social baseline conditions in the Project area, i.e., the existing physical, biological and socio-economic conditions before the HPP's implementation. The determination of the baseline status of the Project area is essential to assess the significance of the negative and positive impacts to be eventually delivered.

The following aspects are considered:

- Physical Environment
- Biological Environment
- Human Environment

The information presented in this section is collected primarily from field surveys and consultation of the DPR (2026 update). Other sources of information are literature research and engagement with stakeholders.

Along with a description of the existing physical, biological and human environment in the Project-affected area, this chapter classifies the degree of sensitivity of the receptors to impacts according to the methodology described in Chapter 5.2. Annexes 5, 6, and 7 contain detailed site surveys reports.

7.1 Physical Environment

7.1.1 Meteorology

Baseline wind speed and direction were monitored at each of the ten ANSP (air and noise sampling points) during the dry/Spring season (April 2025), and the wet/monsoon/Summer season (July 2025). The location of these stations is shown in Figure 13 in Chapter 5.1.1.2.

Atmospheric stability and stagnation

The most critical seasonal difference is atmospheric stability. The dry season is characterized by a highly mechanically stable atmosphere with extreme stagnation, particularly at sheltered sites like ANSP-1 (81.5% calm) and ANSP-3 (68% calm). This severely limits natural pollutant dispersion. In contrast, the wet season is far more dynamic, with calm frequencies dropping significantly across all sites. For example, ANSP-9 (Nayakha Village) transforms from a stagnant area (52% calm) to the most actively ventilated site (24% calm), greatly enhancing its dispersion capacity.

Dominant Wind Patterns

The Project's AoI is dominated by a topographically-driven up-valley (southerly to south-westerly) wind flow, which is present in the dry season but becomes stronger, more persistent, and more organized during the wet season. This establishes a predictable transport pathway from southern activity zones (quarry, stockpiles) towards northern sensitive receptors (Nayakha, Lobnekha Heritage Village). Localized channelling is also evident, especially at ANSP-2 (Tshimalakha), where winds align with the local valley orientation.

Wind Speeds and Extremes

The dry season exhibits greater extremes, with generally low wind speeds punctuated by a zone of high, turbulent wind at the exposed ANSP-7 (Workshop Area), which recorded the year's maximum speed of 4.8 m/s. During the wet season, wind speeds are more moderate but also more consistent across the AoI, with the localized high-speed zone at ANSP-7 becoming less pronounced.

7.1.2 Soil quality

The initial survey of soil quality in April 2025 (dry/Spring season) covered four (4) general soil sampling points (SSP-1 to SSP-4). The survey area was expanded in July 2025 (wet/monsoon/Summer season) to include four (4) additional targeted locations (SSP-05 to SSP-08) aligned with the planned footprints of major facilities such as the workshop, labour camps, and batching plant. The location of the sampling sites is shown in Figure 15 in Chapter 5.1.1.2.

The numeric results are shown in **Error! Reference source not found. Error! Reference source not found.**. An analysis of the results is presented below.

Physical properties

Soils are predominantly loamy, ranging from Sandy Loam to Sandy Clay Loam—ideal for agriculture and revegetation. pH levels are acidic to near-neutral (4.65–6.94), providing a useful baseline for detecting future chemical changes. Porosity (36–46%) and water holding capacity (32–43%) are moderate and typical of loamy soils.

Nutrient and organic content

Organic carbon levels vary, with most sites showing healthy values (>0.95%), indicating rich topsoil suitable for rehabilitation. Nitrogen, phosphate, and potassium levels are generally adequate, confirming soil fertility across the area.

Heavy metals and contaminants

All tested sites showed concentrations of heavy metals - including arsenic, cadmium, mercury, lead, chromium, and nickel - well below CCME guideline limits[17]. No signs of industrial or human-caused contamination were found, confirming a pristine chemical baseline.

7.1.3 Geological and geospatial aspects

The rock present in Bunakha is of crystalline Thimphu Gneissic Complex belonging to upper amphibolite facies of metamorphism. These bedrocks at the site are characterized by heterogeneous lithology consisting of foliated gneisses (feldspar rich), streaky and banded gneisses (granitic gneisses), amphibolite gneisses with large boudins and bands of quartzite and thin interlayer of mica schists/ foliated gneisses with large porphyroblasts of garnet measuring up to 4 mm and bands of calc-silicate gneisses. These form the foundation rocks of the proposed dam. Further details can be consulted in the Annexes to the updated DPR (February 2026).

Groundwater conditions are variable and may lead to seepage or local instability in underground works. Key geotechnical challenges expected include overbreak in tunnelling, rock support

[17] Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the Protection of Environmental and Human Health for Residential/Parkland use - see Chapter 2.8.4.

demands due to jointed and weathered rock masses, slope instability, and variability in permeability.

7.1.3.1 Landslide areas in the reservoir and its vicinity

Potentially unstable slopes were identified during the initial site visit in January 2025 on the right bank, upstream of the dam. Concerns were raised by the DPR Team that similar areas will probably exist around the rim of the reservoir. For this reason, the updated DPR (February 2026) provides a comprehensive landslide inventory in the Bunakha reservoir area and its vicinity. The landslide inventory combined walk-over surveys, field mapping, verifying remote sensing report (TRE Altamira), and hazard–risk assessments to characterize 20 identified landslides and 5 terrain instability zones identified by TRE Altamira.

Initially, 51 landslides were identified from satellite images observation. Subsequently, most of the identified landslides were checked on site via a detailed walk over survey along the reservoir rim from 29 August to 1 September 2025. The survey allowed evaluating the extent, activity, and potential impact of landslides on the Project, associated infrastructure and surrounding communities.

The slides vary significantly in scale, morphology, and activity state (Figure 29). Smaller failures (e.g., LS1, LS2, LS3) are typically shallow rotational slides or debris falls, with limited impact zones. These were classified as low priority (P4) and require only regular visual monitoring, signage, and bio-engineering. A larger set of slides such as LS5, LS6, LS7, LS9, LS10, LS11, LS13, LS14, LS15, and LS18 fall into the moderate category (P3). These sites commonly intersect road sections, plunge pools, or public access areas, and although their hazard scores are not critical, they may require surface drainage, regrading, retaining structures, and periodic patrols to minimize risks.

The inventory confirms that systematic monitoring, timely stabilization, and staged mitigation are vital for maintaining slope stability and ensuring the safety of the hydropower plant and other infrastructure. Low-priority landslides can be managed effectively through monitoring and bio-engineering, whereas high-priority landslides demand immediate engineering interventions after detailed investigations combined with continuous monitoring.

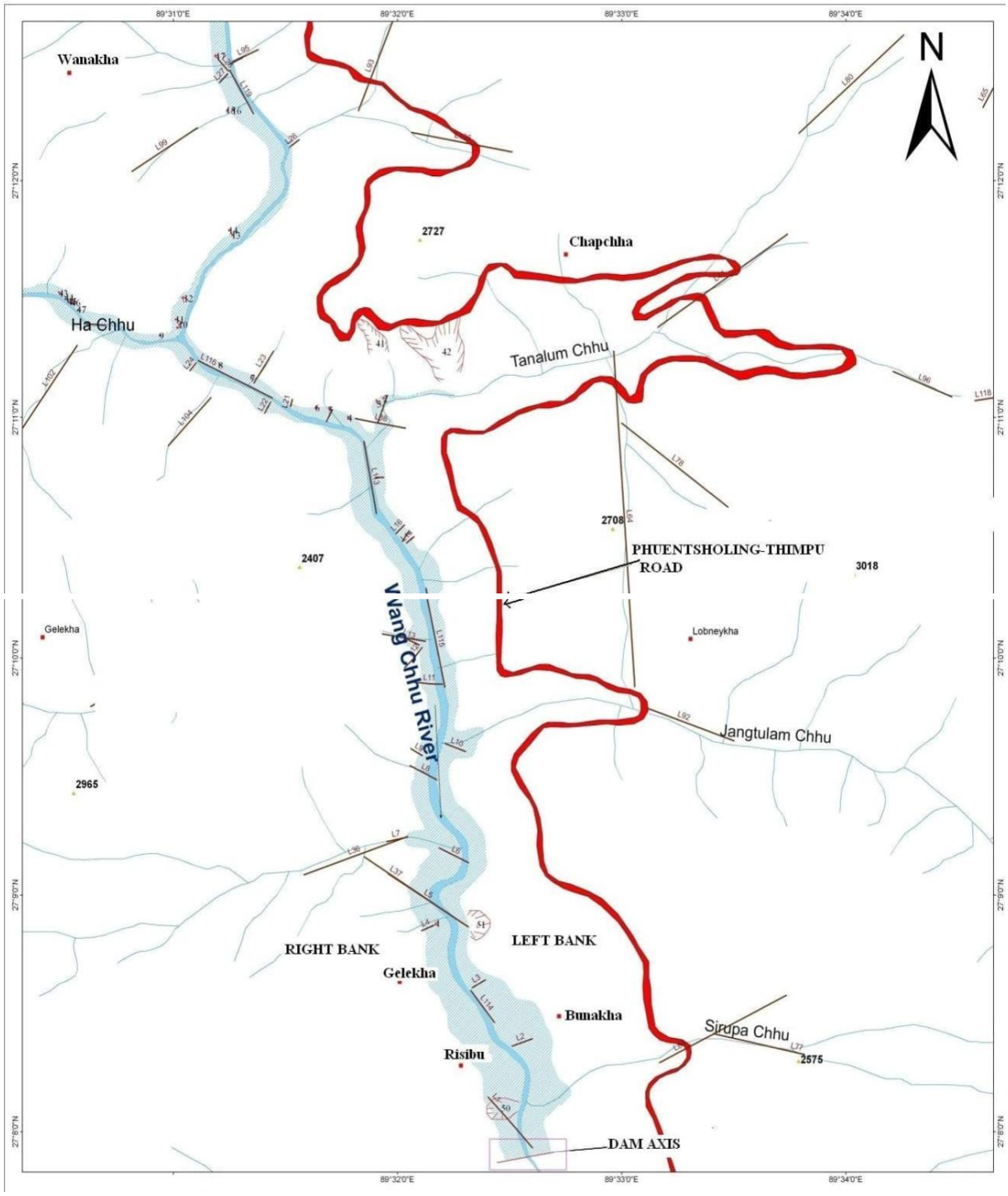


Figure 29: Landslide and lineament map of the study area (Updated DPR, February 2026)

The project area is accessed primarily through the Phuentsholing Highway, which serves as a major national transportation corridor. The year-round operability of this highway is critical for project logistics, transportation of materials, and overall project progress. Therefore, a proper communication channel should be developed and implemented to ensure uninterrupted access, particularly during the monsoon season when slope-related hazards and road disruptions are more likely to occur.

The existing access road passing through Chanachen Village requires improvement and widening to ensure safe and efficient transportation during project implementation. Minor slope instabilities are anticipated along several sections of the road corridor due to the steep terrain and unconsolidated slope materials. Appropriate slope stabilization measures, including the construction of gabion walls and masonry retaining structures, are recommended to mitigate the risk of localized failures and maintain road stability.

The left-bank dam access road traverses a nala where road construction activities may trigger slope failures within existing debris deposits. Although masonry retaining walls have been proposed in this section, periodic damage and deterioration may occur during the monsoon season due to increased runoff and erosion. Consequently, regular inspection, maintenance, and, where necessary, reconstruction or reinforcement of the retaining structures will be required during and after the monsoon period. Travel along this section should be minimized or avoided during periods of intense rainfall due to the elevated risk of slope instability and road damage.

Seasonal monsoonal conditions may also result in localized disturbances such as minor landslides, debris accumulation, and drainage-related erosion along the other access routes and Chanachen village. However, with timely clearance of debris, routine maintenance, road accessibility can generally be maintained throughout the year.

The walk=over landslide survey confirmed that systematic monitoring, timely stabilization, and staged mitigation are vital for maintaining slope stability and ensuring safety. Low-priority landslides can be managed effectively through monitoring and bioengineering, whereas high-priority landslides demand immediate engineering interventions after detailed investigations combined with continuous monitoring.

TRE ALTAMIRA also carried out ground movement study through satellite images (Sentinel and Alos) and especially in some of their findings in and around the dam area, slope movement could be observed indirectly through the bending of trees, water seepages and/or relict landslides. These need to be studied in detail to include the mitigation options for these slopes/slides and are included in the report as high to very high priority. In the case of those movements identified along the Damchu-Haa bypass, no direct movement could be observed, but the project needs to also monitor these identified observations for long term stability of the reservoir.

By integrating these recommendations into the planning and implementation stages, the Bunakha Hydropower Project can significantly reduce geohazard risks, safeguard its infrastructure, and ensure **long-term operational reliability** while protecting the surrounding communities and environment.

7.1.3.2 Slope Stability

Underground Work

Excavation will be carried out using drilling and controlled blasting, suitable for the site's rock conditions and underground structures. Large caverns like the powerhouse and transformer caverns will be excavated in stages, with immediate installation of primary supports such as rock bolts, shotcrete, and DCP bolts to maintain rock stability and reduce deformation.

For waterway tunnels, a heading-and-benching method will be used, where the upper section is excavated first, followed by the lower section. After each blast cycle, rock support is installed

promptly to stabilize exposed surfaces. This sequential excavation and support system ensures safe and stable tunneling throughout construction.

Surface Works

The slope design uses a 2V:1H overall inclination with berms to maintain stability during excavation and long-term performance. Berms are protected with shotcrete and combined with hillside drainage ditches to divert runoff and reduce erosion. Additional drainage holes (6 m long, spaced at about 16 m²) are installed to relieve pore water pressure and improve rock mass stability.

Before tunnel portal excavation, a lattice girder system is installed, followed by shotcrete and 6 m rock bolts at 0.5 m spacing for immediate slope support. Support measures vary with rock conditions: in Grade III weathered rock, 10 cm shotcrete and 6 m bolts at 4 m² spacing are used, while in Grade II better rock, 5 cm shotcrete and 4 m bolts at 9 m² spacing are applied.

At the dam plinth and abutment areas, only thin shotcrete is generally used for shaping, with efforts made to expose fresh rock for a stable foundation, though local reinforcement is applied where weak zones exist.

7.1.3.3 Blast Design

Blasting for the BHPP is necessary for excavation works associated with the dam abutment, tunnels, powerhouse complex, shafts, and access roads. However, blasting activities may induce ground vibrations that can affect the stability of nearby slopes, excavated faces, and weathered rock masses.

The project area is predominantly underlain by crystalline Thimphu Gneissic rocks comprising gneisses, amphibolites, quartzite bands, and mica schists. While these rocks generally provide competent foundations, the presence of weak zones creates discontinuities that may be adversely affected by blasting-induced vibrations.

Particular attention is required near the dam slope area and the adjacent nala, where approximately 20 m of colluvial deposits along the hillside and alluvial fan deposits associated along the nala channel overlie the underlying bedrock. These loose and unconsolidated materials are more vulnerable to blasting-induced vibrations than the surrounding rock mass. If blasting is not carefully controlled, localized slope failures, minor ground settlement, erosion, or loosening of surficial materials may occur, particularly in areas where the deposits are thickest or already affected by natural weathering and drainage processes.

To minimize these risks, all blasting works shall be carried out using controlled blasting techniques as indicated in 13.5.21 Blasting Operation.

7.1.3.4 Excavation Sequencing

The dam foundation and portal excavations for the BHPP are planned to be carried out using the drilling and blasting method. For the dam excavation, abutment stripping and excavation above the river water level on both banks will be completed prior to river diversion, while excavation below the river water level will be undertaken after the construction of the upstream cofferdam. Open excavation of the left and right bank abutments in rock is planned to be carried out using the deep-hole bench drilling and blasting method.

Underground Work

Excavation will be carried out using drilling and controlled blasting, suitable for the site's rock conditions and underground structures. Large caverns like the powerhouse and transformer caverns will be excavated in stages, with immediate installation of primary supports such as rock bolts, shotcrete, and DCP bolts to maintain rock stability and reduce deformation.

For large tunnel like waterway tunnels, a heading-and-benching method will be used, where the upper section is excavated first, followed by the lower section. After each blast cycle, rock support is installed promptly to stabilize exposed surfaces. This sequential excavation and support system ensures safe and stable tunneling throughout construction.

Surface Excavation Works and Cut Slope Collapse

Construction of access roads, tunnel portal areas, quarry benches, and dam abutment excavations may induce slope instability where excavations intersect adverse geological structures, weathered rock zones, or groundwater seepage areas. Potential failure mechanisms include planar failure, wedge failure, toppling, ravelling, and shallow debris slides. The risk of instability is further increased during periods of intense rainfall, blasting activities, and prolonged exposure of unsupported slopes.

The overall slope design has been developed based on site geological conditions and incorporates the following general inclination parameters:

Berm slope: 2V:1H

Overburden material slope: 3V:1H

Weathered rock: 5V:1H

Slightly weathered to fresh rock: 10V:1H

These slope configurations, together with intermediate berms, are intended to enhance overall slope stability, reduce the risk of mass movement, and facilitate effective surface and subsurface drainage. Berms will be protected with shotcrete and provided with hillside drainage ditches to intercept and safely divert runoff, thereby minimizing erosion and water infiltration into the slope mass. In addition, drainage holes (approximately 6 m long, spaced at about 16 m²) will be installed to relieve pore water pressure and improve overall rock mass stability.

At tunnel portal areas, a lattice girder system will be installed prior to excavation, followed by shotcrete and systematic rock bolting (6 m bolts at 2m spacing) to provide immediate slope support. Support intensity will vary depending on rock mass quality: in Grade III weathered rock, 10 cm shotcrete and 6 m bolts at 4 m² spacing will be applied, while in Grade II slightly weathered rock, 5 cm shotcrete and 4 m bolts at 9 m² spacing will be used.

At the dam plinth and abutment areas, only thin shotcrete will generally be applied for surface protection and shaping, with efforts made to expose fresh competent rock for foundation stability. However, localized reinforcement measures will be implemented where weak zones, discontinuities, or weathered pockets are encountered.

7.1.3.5 Quarry Stability

Quarry development for construction materials may create steep excavation faces and benches that are susceptible to localized instability. Geological discontinuities, weathering, blasting damage, groundwater ingress, and improper bench geometry may contribute to slope failures within quarry areas. Failure of quarry slopes may pose risks to workers, equipment, haul roads, and material production activities.

Quarry operations shall follow approved benching designs with controlled bench heights, widths, and face angles appropriate to the rock mass conditions. Regular geotechnical inspections of all quarries faces and benches shall be carried out throughout the operational period, and controlled blasting techniques shall be implemented during face development to minimize damage to final quarry walls.

7.1.4 Seismo-tectonics

According to the updated DPR (February 2026), the Bunakha HPP is located in the highly seismic Himalayan tectonic belt and falls in the vicinity of Seismic Zone – V of the Seismic Zonation Map of India as per IS:1893 - (part 1) 2002. Due to the identified seismic activity in regions in close proximity to the Bunakha HPP site, ensuring seismic resilience is critically important. The closer distance to seismically active zones, marked by tectonic features such as the Main Central Thrust (MCT) and Main Boundary Thrust (MBT), requires durable earthquake-resistant design measures to secure the project infrastructure against likely seismic events.

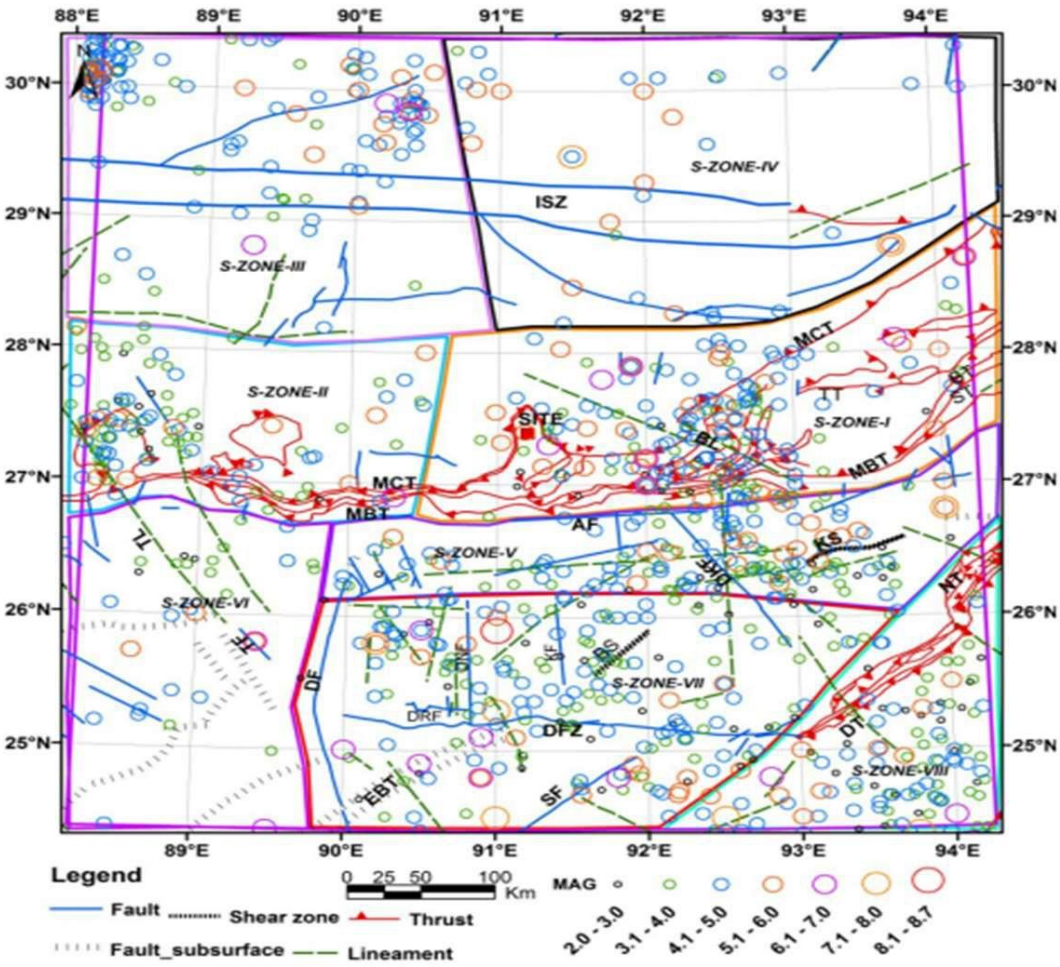


Figure 30: Seismicity zonation map showing major fault and thrust, Seismicity and seismogenic source zones provided by the Department of Earthquake Engineering, Indian Institute of Technology Roorkee (2015)

The Seismic Study prepared by Roorkee in 2009, will need to be updated considering the earthquakes that occurred in the region since then, and considering the changes in the respective ICOLD standards. The site specific design earthquake parameters evaluated by IIT, Roorkee are hence no longer valid and for this reason no further details are given in this ESIA report. It is recommended that once the report is updated and finalised its findings should be incorporated into the Site specific ESMP.

7.1.5 Hydrology of the basin

Wangchu River basin is one of the four major river basins of Bhutan, the other three being Amochu, Punatssangchu (Samkosh), and Dangmechu (Manas). The Wangchu, also known as Raidak, originates from om Jomolhari at 7,326 m. The river drains about 4,600 km² at the Bhutan-India border. The Pachu, Thimchu and Hachu are the major tributaries of Wangchu. Figure 31 shows the streamflow as observed on 21 January 2025 at the dam site.

Figure 31: Streamflow at damsite and watershed looking u/s from the dam site on 21 Jan 2025

Further detail information is available in Chapter 3.3.1.

Basin-Wide Sediment Balance

The basin-wide sediment balance has been assessed using regional statistical models developed for the Hindu Kush–Himalayan region and the Central Water Commission (CWC) guidelines for North India, together with conceptual sediment yield estimation based on the Revised Universal Soil Loss Equation (RUSLE) and the Pacific Southwest Inter-Agency Committee (PSIAC) method.

Since approximately 90% of the Wangchhu river basin is covered with forest or wooden grass lands, and since it is a relatively dry sub-basin of the Brahmaputra basin, lower range of the sediment map may be adopted for the sediment yield of the Wangchhu basin. Accordingly, the regional average basin-wide sediment yield may be expected at 750 t/km^2.

7.1.6 Water resources

The Wangchhu river basin, draining 3,541 km^2 at Bunakha originates from the Mount Jomolhari (7,314 m) at the Bhutan-China border. The Wangchhu is a snow-fed river with 3% of the area above 5,000 m and approximately 75% of the area above 3,000 m. There are about 36 glaciers and more than 12 glacial lakes with an area exceeding 0.01 km^2. Most of the glaciers and glacial lakes are located within the elevation range of 4,000 m to 5,000 m.

The major sub-basins of the Wangchhu are i) the Thimchhu, draining the most parts of the Thimphu Dzongkhag (district); ii) the Pachhu, draining the Paro Dzongkhag; iii) and the Haachhu, draining some parts the Haa Dzongkhag.

The Wangchhu basin is the most populous basin of Bhutan. Although it occupies approximately 9% of the country's area, it provides shelter to about 30% of the population. 21% of the Bhutanese population lives in the Thimphu Dzongkhag.

Areas between 3,000 m and 4,000 m are mainly covered by coniferous forests. Areas below 3,000 m are dominated by deciduous and mixed forests. Although arable lands are found in most of the valleys, they are dominating in the Pachhu valley. The agriculture lands in the Pachhu watershed exceeds 5%, which is significantly higher than the national average estimated at 2.9%. The other vegetative cover includes shrublands and grasslands.

Because of the wide topographical variations, the Wangchhu basin experiences mainly temperate climate in the south and alpine climate in the north. The distinct four seasons include: spring

(March to May), summer (June to August), autumn (September to November) and winter (December to February).

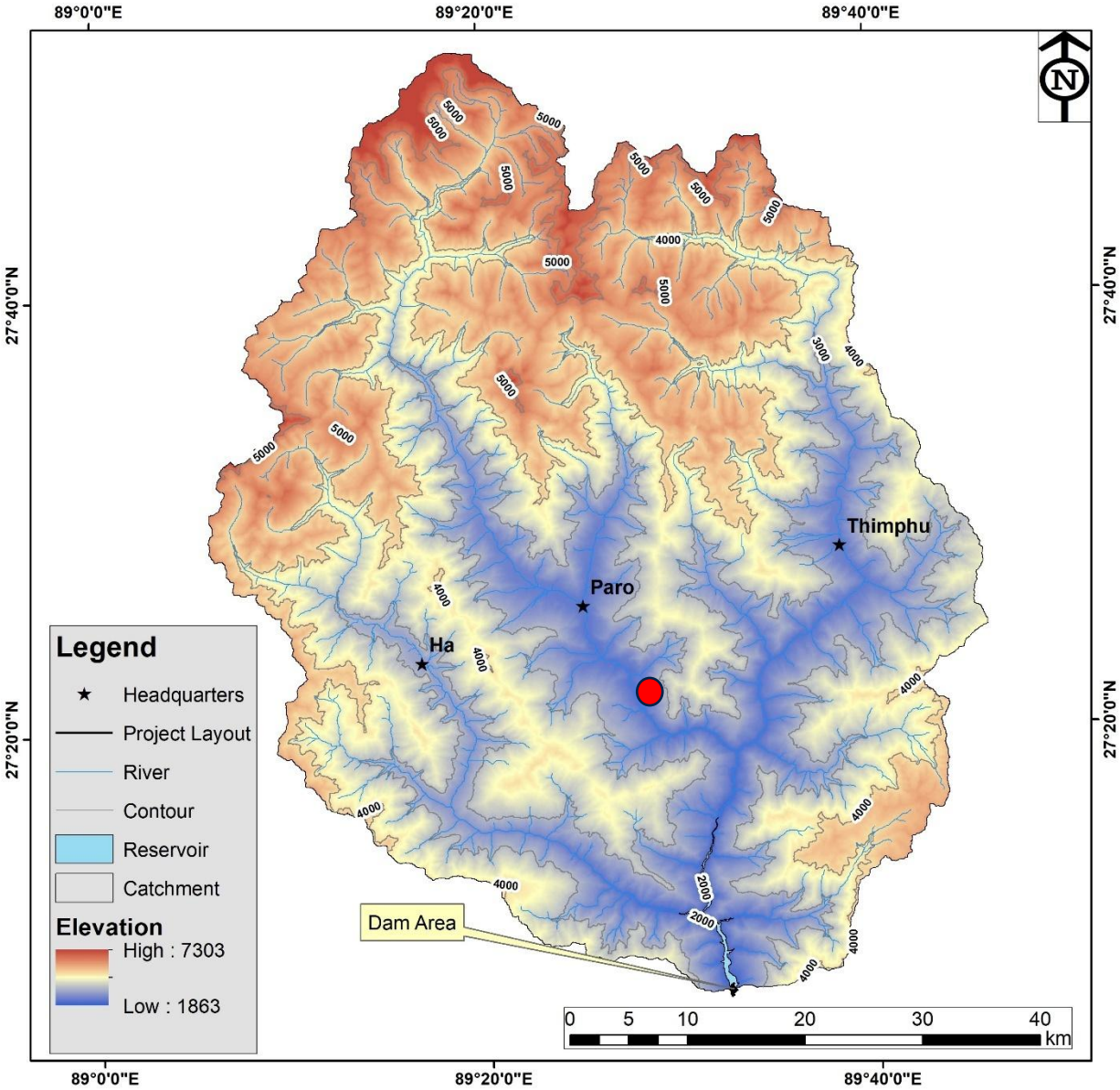


Figure 32: Topographical variation of the Wangchhu basin upstream of the Bunakha HPP

7.1.7 Water quality

A 3-seasons water quality monitoring program was undertaken to build an environmental baseline for the Bunakha HPP. Initially, eight (8) sampling sites were set up during the dry/Spring season, and this network was expanded to ten (10) sites during the wet/monsoon/Summer season and the post-monsoon/Autumn season with the inclusion of two (2) additional community water sources.

In summary, the Wangchhu River and its major tributaries' surface water (SW) are sampled via SW-1, SW-2, SW-3, SW-4, SW-6 and SW-8; and the community springs that serve as primary drinking water sources are sampled via SW-5, SW-7, SW-9, and SW-10. The locations of the sampling sites are illustrated in Figure 14 in Chapter 5.1.1.2.

The surveys show that the water in the Project area is chemically pure, highlighting the largely untouched and natural condition of the upper Wangchhu catchment and nearby community water sources. However, seasonal variations—especially in physical properties and bacterial levels—may pose challenges for Project operations and potential health risks for surrounding communities. The numeric results are shown in **Error! Reference source not found. Error! Reference source not found.**. An analysis of the results is presented below.

Fourth season water quality monitoring was not conducted, as from a technical perspective, the absence of winter water quality data presents a relatively low risk, as conditions during winter in the Wangchhu River catchment are expected to be comparable to those observed in the dry season.

Details given in Table 22 Nature and status of the baseline surveys undertaken for the Bunakha HPP and Annex 4 Report on the physical environment surveys.

7.1.7.1 Detailed seasonal analysis

Physical parameters (TSS, Turbidity, TDS, Conductivity)

During the dry season (April 2025), the hydrological system exhibited exceptional clarity across the board. Both the river and tributaries (SW-1, SW-2, SW-3, SW-4, SW-6, and SW-8) and the sampled community drinking water sources (SW-5 and SW-7) recorded Total Suspended Solids (TSS) and Turbidity below detectable levels. This reflects ideal low-flow conditions with minimal surface runoff. Total Dissolved Solids (TDS) and Electrical Conductivity were also low (e.g., TDS ~48–72 mg/L), indicating water with very little mineral content, typical of snowmelt and groundwater-fed mountain systems.

In contrast, the wet season (June 2025) brought significant changes due to monsoon rains primarily affecting the rivers and tributaries. TSS levels rose to measurable concentrations (4–8 mg/L), still well within Bhutan's ES 2020 Class B standard (<100 mg/L), but clearly showing the impact of increased runoff and erosion. TDS and Conductivity also rose in the river, pointing to the flushing of minerals and salts from the catchment area. For the community drinking water sources (SW-5, SW-7, SW-9, and SW-10), turbidity remained very low at <1.0 NTU.

By November 2025 (post-monsoon), the physical characteristics of the water showed a clear divergence based on the source type and size:

- River and tributaries: The Wangchhu River and its tributaries sites (SW-1 to SW-4) retained TSS levels similar to the wet season (4–8 mg/L), suggesting that fine sediments remain suspended in the larger water bodies even as flows recede. Conductivity also remained elevated compared to the dry season (146–157 µS/cm). However, the smaller tributaries within this category (SW-6 Motolumchhu and SW-8 Zanteylum chhu) cleared up significantly, with TSS returning to below detectable limits (<2.5 mg/L).
- Community drinking water sources (SW-5, SW-7, SW-9, SW-10): All four community drinking water sources demonstrated pristine physical clarity, with TSS below detectable limits (<2.5 mg/L) and turbidity at <1.0 NTU. Full parameter testing resumed for SW-05 (Tsimasham Drinking Water) during this period, confirming excellent overall physical health (TDS at 62 mg/L and Conductivity at 111 µS/cm).

These findings suggest that while the main river system has a lingering sensitivity to sediment load, the local springs and tributaries recover their clarity rapidly after the monsoon.

Bacteriological parameters (Total and Faecal Coliforms)

During the dry season, all sampled locations showed signs of bacteriological contamination. Within the Wangchuu river and its tributaries (SW-1, SW-2, SW-3, SW-4, SW-6, and SW-8), Faecal Coliforms ranged from 4 to 6 MPN/100ml. Critically, the two community drinking water sources sampled during this phase (SW-5 and SW-7) also recorded Faecal Coliform levels of 2 and 8 MPN/100ml respectively, failing to meet Bhutan's ES 2020 drinking water standard (0 MPN/100ml or "Not Detected"). This suggests a baseline of low-level pollution from animal or human waste during low-flow periods.

In the wet season, contamination slightly increased, especially in river sites (SW-1 to SW-4), where Faecal Coliform counts rose to 4–11 MPN/100ml. This rise is consistent with monsoon runoff carrying pollutants from broader areas into the water system. In contrast, all community drinking water sources (SW-5, SW-7, SW-9 and SW-10) showed very low or non-detectable levels (<2 MPN/100ml), likely due to the high dilution factor of heavy monsoon rains.

During the post-monsoon season, a distinct contrast emerged in the microbiological profile:

- River water deterioration: The main river sites (SW-1 to SW-4) showed the highest contamination levels of the year. Total Coliforms reached 48 MPN/100ml and Faecal Coliforms peaked at 17 MPN/100ml (SW-01). This increase during the recession of high flows may be attributed to the "concentration effect" as water volumes decrease while localized pollutant loads from the catchment remain.
- Clear tributaries and community drinking water sources: The smaller streams (SW-6 Motolumchhu, and SW-8 Zanteylum chhu) and all four community drinking water sources (SW-5, SW-7, SW-9, SW-10) were found to be bacteriologically clean (<2 MPN/100ml for both Total and Faecal Coliforms).

Despite the clean results during the wet and post-monsoon periods for the community sources, the confirmed presence of faecal contamination during the dry season demonstrates that these drinking water supplies are highly vulnerable to seasonal fluctuations. Therefore, no community spring in the project area can be considered safe for year-round consumption without proper water treatment.

Chemical Parameters (pH, DO, Nutrients, Heavy Metals)

The chemical quality of water across the Project area is outstanding and remains consistently stable across the three monitoring seasons.

- pH: levels remained neutral to slightly alkaline (ranging from 7.04 to 8.06) across all 10 sites, which is well within both the Class B River and National Drinking Water standards, representing ideal conditions for aquatic life and human consumption.
- Dissolved Oxygen (DO): the surface waters remain exceptionally well-oxygenated. Notably, DO levels reached their peak during the cooler post-monsoon season, recording a high of 10.0 mg/L at SW-3 (Jhililumchhu tributary), indicating a robust and healthy aquatic ecosystem capable of supporting sensitive species.

- Organics (BOD and COD): during the dry and wet seasons, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were generally below detection limits across all relevant sites. In the post-monsoon season, trace levels of BOD (0.5–1.2 mg/L) and COD (1.9–3.8 mg/L) were detected across the network. These values are extremely low, well within the applicable environmental standards, and simply indicate a natural, slight accumulation of decomposing organic matter following the heavy monsoon biomass flush.
- Nutrients (Nitrates, Phosphates): nutrient levels were consistently negligible, remaining well below the required thresholds for both river classifications and drinking water safety, indicating no significant agricultural fertilizer runoff in the immediate catchments.
- Heavy metals and organic pollutants: across all three seasons, tests for heavy metals (Lead, Mercury, Cadmium, Arsenic, Chromium) and toxic organic pollutants (Phenols, Pesticides, PAHs, Cyanide) returned results that were consistently Below Detection Limits (BDL) or well below permissible standards at all 10 monitoring locations.

The results establish a pristine chemical baseline. Any future detection of heavy metals or hydrocarbons would serve as a potential indicator of Project-related impact.

7.1.7.2 Analysis of community drinking water sources

Several sources within the Area of Influence have been identified as existing or potential drinking water supplies and must be evaluated against the stricter safety thresholds of the Bhutanese Drinking Water Quality Standards (2016):

- SW-5: Tsimasham Drinking Water
- SW-7: Chomteykha Spring Water
- SW-9: Nayakha Chhu (a stream directly utilized by Nayakha village as a primary water source)
- SW-10: Chanachen Village Spring

For these four critical community sources, the seasonal monitoring reveals the following baseline conditions to inform Project planning and worker health strategies:

- Chemical safety: Across all monitored seasons (dry, wet, and post-monsoon), these sources were found to be chemically pristine, with no heavy metals, toxic compounds or agricultural-resulting nutrients detected. From a purely chemical standpoint, these sources are safe for consumption.
- Microbiological vulnerability: The biological safety of these sources fluctuates significantly with the seasons.
  - Dry season: Contamination (Faecal Coliforms) was detected in sources SW-5 and SW-7, violating the national standard of zero detectible coliforms and indicating a persistent baseline of low-level human or animal waste pollution during low-flow periods.
  - Wet & post-monsoon seasons: Sources appeared bacteriologically cleaner (<2 MPN/100ml), likely due to the high dilution factor of monsoon rains and subsequent systemic flushing.

In conclusion, despite the chemically safe baseline, the presence of faecal contamination during the dry season renders the Project area's natural drinking water sources fundamentally unreliable for direct human consumption. The clear results in the wet and post-monsoon seasons do not negate the risk observed in the dry season. Therefore, the Project cannot rely on the raw, untreated water quality of these sources being consistently/year-round safe.

7.1.8 Air quality

The monitoring of air quality was conducted during both the dry season (April 2025) and the wet season (July 2025) to capture seasonal variations. The location of the air quality monitoring stations is shown in Figure 13 in Chapter 5.1.1.2.

The baseline data reveals a Project area with significant air quality challenges. While compliance with Bhutan's national standards is mixed, the data shows widespread and persistent exceedances of the stricter, health-based World Health Organization (WHO) Air Quality Guidelines across both seasons. The numeric results are shown in **Error! Reference source not found. Error! Reference source not found.**. An analysis of the results is presented below.

Compliance with National Standards (ES 2020)

During the wet season, all monitored parameters at all ten locations were found to be in full compliance with the national ES 2020 limits for mixed areas.

During the dry season, however, exceedances for two key pollutants were recorded:

- Ozone (O_3): Five of the nine monitored sites showed 8-hour mean concentrations exceeding the national standard of 100 µg/m³. The most significant exceedances were recorded at ANSP-3 (Damsite), ANSP-4 (Bunakha Lhakhang), ANSP-6 (Stockyard), ANSP-7 (Campsite), and ANSP-8 (Zangtey).
- Sulphur Dioxide (SO_2): One location, ANSP-6 (Stockyard), recorded a 24-hour mean SO_2 concentration of 96.6 µg/m³, which is above the national limit of 80 µg/m³.

All other parameters, including Nitrogen Dioxide (NO_2), Particulate Matter ($PM_{2.5}$ and PM_{10}), and Carbon Monoxide (CO), were found to be well within the national ES 2020 limits at all locations during the dry season.

Comparison with WHO Guidelines (AQG 2021)

When benchmarked against the more stringent WHO guidelines designed to protect public health, the baseline data indicates a pre-stressed airshed with multiple pollutants of concern year-round.

- Nitrogen Dioxide (NO_2): This is the most critical and persistent pollutant. Concentrations at all ten sites during both the dry and wet seasons substantially exceeded the WHO's 24-hour guideline of 10 µg/m³, often by a factor of four to six. This confirms a significant, year-round air quality issue driven by regional sources, potentially primarily emissions from traffic.
- Fine Particulate Matter ($PM_{2.5}$): High $PM_{2.5}$ values can become a major health concern, with levels varying significantly by season at the Project's AoI. Considering the WHO guideline of 5 µg/m³:
  - During the dry season, widespread exceedances were recorded at eight of the nine sites, with concentrations reaching up to 27.1 µg/m³ (over five times the guideline). Only ANSP-3 (Damsite) was compliant.
  - During the wet season, the "washout" effect of rain dramatically reduced levels, but four locations (ANSP-3, ANSP-6, ANSP-9, and ANSP-10) still recorded values at or slightly above the WHO guideline.
- Ozone (O_3): Exceedances of the WHO 8-hour guideline of 60 µg/m³ were a significant concern in both seasons, indicating conditions conducive to photochemical smog.

- During the dry season, six of the nine sites (ANSP-3, ANSP-4, ANSP-5, ANSP-6, ANSP-7, and ANSP-8) recorded concentrations well above the guideline.
- During the wet season, five sites (ANSP-1, ANSP-2, ANSP-5, ANSP-7, and ANSP-9) also exceeded the WHO guideline, highlighting that ozone formation remains a risk even during the monsoon period.

- Sulphur Dioxide (SO_2): Intermittent exceedances of the WHO 24-hour guideline (40 µg/m³) were observed, suggesting localized hot-spots:
  - During the dry season, five sites (ANSP-3, ANSP-4, ANSP-6, ANSP-7, and ANSP-8) recorded exceedances.
  - During the wet season, three sites (ANSP-5, ANSP-7, and ANSP-9) showed concentrations above the WHO guideline.
- Particulate Matter (PM_{10}): While compliant during the wet season, concentrations of PM_{10} were a concern during the dry season. Four locations (ANSP-2, ANSP-4, ANSP-5, and ANSP-9) recorded levels exceeding the WHO 24-hour guideline of 15 µg/m³.
- Other pollutants (TSP and Carbon Monoxide): Concentrations of TSP have no corresponding WHO guideline. Carbon Monoxide (CO) levels were 0.0 mg/m³ at all sites during both surveys, remaining in full compliance with the WHO guideline.

7.1.8.1 Analysis of spatial and temporal variations

The baseline data reveals a strong and predictable seasonal influence on ambient air quality, driven by the region's distinct meteorological shifts. This dynamic creates different air quality challenges in each period.

Dry season (April) conditions

Dominated by stagnation and photochemistry, this period is characterized by poor atmospheric dispersion and intense solar radiation, leading to the highest concentrations of most pollutants.

- Severe build-up of primary pollutants ($PM_{2.5}$, NO_2, CO): The wind rose data confirms a high frequency of calm, stable atmospheric conditions. This inhibits the dispersion of primary pollutants, causing concentrations of $PM_{2.5}$, NO_2, and especially CO to build up to their highest annual levels. The extreme exceedances of WHO guidelines for these pollutants are largely exclusive to this season.
- High photochemical smog formation (O_3): The combination of strong sunlight and stagnant air containing high concentrations of precursor pollutants (NOx) acts as a powerful catalyst for photochemical reactions. This results in the formation of significant secondary pollution, leading to widespread exceedances of both national and WHO standards for ground-level Ozone (O_3).

Wet season (July) conditions

Dominated by atmospheric cleansing and transport, the monsoon period is characterized by improved dispersion, which significantly alters the pollution profile, though critical issues remain.

- Reduction of $PM_{2.5}$ and CO: Frequent and heavy monsoon rains lead to the "washout" (wet deposition) of particulate matter and the efficient dispersion of gases like CO. This atmospheric cleansing explains the significant drop in both $PM_{2.5}$ and CO concentrations, which fall to levels well within all guidelines.
- Persistence of primary pollutants (NO_2): Despite the rain, baseline levels of NO_2 remain high, continuing to exceed WHO guidelines at all ten locations. This confirms the presence of a

persistent, significant year-round emission source (i.e., highway traffic) whose concentrations are not sufficiently mitigated by wet season conditions.

- Suppression of ozone: As expected, increased cloud cover and reduced solar radiation during the monsoon almost completely suppress the photochemical processes necessary for O_3 formation. Consequently, ozone levels fall to well within all national and international guidelines during this period.

Spatial variation (source-receptor dynamics)

The monitoring data, interpreted through the lens of seasonal wind patterns, reveals a clear spatial distribution of pollutants that directly links pollution hotspots to the primary regional emission source.

The spatial data collected points to the Thimphu-Phuentsholing Highway corridor as the possible dominant source of pollution in the region. The following is highlighted:

- High NO_2: The highest concentrations of NO_2 were consistently recorded at locations directly adjacent to the highway (e.g., ANSP-2, ANSP-4, ANSP-7). This spatial pattern points to vehicular traffic as the eventual primary regional source of NO2. During the dry season, these high emissions, combined with poor dispersion, create a poor air quality corridor.
- High Ozone and SO_2: The highest concentrations of Ozone and Sulphur Dioxide during the dry season were also recorded at sites near the highway, particularly ANSP-6 (Stockyard) and ANSP-8 (Zangtey). This seems to indicate that the precursor pollutants (NOx, VOCs, SO_2) emitted from traffic are fuelling the formation of secondary pollutants and creating localized hotspots under specific meteorological conditions.

Location of receptors

The data shows that pollutants are actively transported from the highway corridor to more remote communities. The remote Nayakha Village (ANSP-9), with few internal emission sources, serves as a clear downwind receptor. It recorded consistently high NO_2 concentrations (~40 µg/m³) in both seasons, well above WHO guidelines. The wind rose analysis for the wet season shows a dominant up-valley (southerly) wind flow, creating a direct transport pathway from the highway corridor toward Nayakha. This defensibly characterizes Nayakha Village as a confirmed downwind sensitive receptor, vulnerable to emissions generated further down the valley.

7.1.9 Noise

Ambient noise levels were monitored over a 48-hour period at ten strategic locations during the dry season (April 2025) and wet season (July 2025). The location of the noise monitoring stations (air and noise sampling points - ANSP) is shown in Figure 13 in Chapter 5.1.1.2.

The baseline noise survey reveals a complex acoustic environment, characterized by quiet rural areas but also influenced by both natural and man-made (anthropogenic) noise sources. The numeric results are shown in **Error! Reference source not found. Error! Reference source not found.**. An analysis of the results is presented below.

Overall compliance and key exceedances

Baseline noise levels generally comply with Bhutan's ES 2020 national standards. The primary exception is the proposed damsite (ANSP-3), where, assumingly, the sound of the Wangchhu

River at peak flow caused the night-time level to reach 68.90 dBA during the wet season, significantly exceeding the 55 dBA limit. This is deemed to be an exceedance caused by natural factors only.

However, the data also points to anthropogenic noise from highway traffic as a major issue. During the dry season, night-time levels at Tshimalakha (ANSP-2) and Bunakha Lhakhang (ANSP-4) exceeded the stricter WHO health-based guidelines (45 dBA).

Identification of acoustically sensitive receptors

Three distinct types of sensitive receptors were identified:

1. Receptors in calm areas: Nayakha village (ANSP-9) and Chanachen Village (ANSP-10) are considered very sensitive to noise due to their low background noise levels, which are about 36-40 dBA. In these quiet places, any noise from construction or blasting will likely stand out and affect the community.
2. Areas with little room for extra noise: The Tshimalakha settlement (ANSP-2) is a sensitive receptor, especially at night. Its average noise level during the dry season is 53.09 dBA, which means there is less than 2 dBA of “margin” before the national limit of 55 dBA is reached.
3. Locations already above health guidelines: Bunakha Lhakhang (ANSP-4) and the Zangtey area of Lobneykha Heritage Village (ANSP-8), both located along the highway, are concerning because their current noise levels are already higher than or very close to the World Health Organization's recommended limits. This means these areas are already experiencing high noise levels that could be harmful.

7.2 Biological Environment

A comprehensive multi-season biodiversity assessment, including biodiversity-relevant water quality parameters, was conducted to establish baseline ecological conditions within the Project’s AoI. The assessment integrated both aquatic and terrestrial ecosystems and was designed to capture seasonal variability and ecological dynamics relevant to impact assessment and mitigation planning.

The methodology used for the biodiversity surveys can be read in Chapter 5.1.2 and Chapter 5.1.3. The detailed site reports are attached in **Error! Reference source not found. Error! Reference source not found.**. This Chapter presents a summary of the results of the surveys.

Based on the site surveys, desktop investigations and experts’ consultation, a Critical Habitat Assessment (CHA) was performed. The summary of the results is presented in this chapter; the full report can be read in **Error! Reference source not found.**.

7.2.1 Aquatic Biodiversity

7.2.1.1 Seasonal Characteristics

The aquatic ecosystem of the Wangchu River within the Bunakha HPP’s AoI exhibits pronounced seasonal variability driven by hydrological fluctuations, sediment dynamics, and habitat connectivity.

- Pre-monsoon/dry/spring season: Low-flow limitation and reduced diversity

- Monsoon/wet/summer season: High diversity but unstable, disturbance-driven system
- Post-monsoon/autumn season: Ecological recovery and stabilization

This seasonal pattern indicates a dynamic yet resilient river system, with ecological integrity largely maintained across hydrological cycles. The consolidated list of fish species recorded across all survey seasons is provided in 0.

Pre-monsoon/dry/spring season

During the pre-monsoon/dry/spring season (March 2025), river discharge was low and hydrological conditions relatively stable. This resulted in reduced habitat availability and limited connectivity between aquatic habitats. Fish diversity was correspondingly low, with only two species recorded, namely *Schizothorax richardsonii* and *Salmo trutta*. On the other hand, macroinvertebrate and plankton communities demonstrated moderate richness, with 16–24 macroinvertebrate families and multiple plankton genera recorded across sites, indicating relatively stable ecological conditions under low-flow scenarios.

Monsoon/wet/summer season

In contrast, the monsoon/wet/summer season (August–September 2025) was characterized by high discharge, increased flow velocity, and elevated sediment transport. These conditions lead to habitat disturbance and redistribution of aquatic organisms. A total of 29 fish species (241 individuals) were recorded during this period, representing the highest species richness across seasons. However, species distribution is highly variable due to washout effects and downstream displacement. Key species include *Neolissochilus hexagonolepis* and *Opsarius barna*, while species of conservation concern such as *Tor putitora* (Endangered - EN) and *Schizothorax richardsonii* (Vulnerable - VU) were also recorded. Macroinvertebrate diversity (26 families) and plankton assemblages indicate generally good ecological conditions despite localized disturbances.

Post-monsoon/autumn season

The post-monsoon/autumn season (November–December 2025) represented an ecological recovery phase, with stabilized flows and improved habitat conditions. Fish diversity decreased to 12 species (195 individuals) but reflected more stable community structures compared to monsoon conditions. Dominant species surveyed included *Neolissochilus hexagonolepis* and *Schizothorax richardsonii*. Macroinvertebrate diversity (12 families) and plankton communities showed recovery trends, and water quality parameters remained within acceptable ecological limits.

7.2.1.2 Seasonal Comparison

Fish

Across all seasons, the Wangchu River supports a diverse assemblage of native Himalayan fish species, with cumulative richness exceeding 28 species based on seasonal surveys. Key findings include:

- Presence of indicator species such as *Schizothorax richardsonii*, characteristic of cold, fast-flowing mountain rivers
- Occurrence of threatened species, including *Tor putitora* (EN), *Schizothorax richardsonii* (VU) and *Semiplotus semiplotus* (VU)

- Dominance of cyprinid species adapted to high-gradient river systems

The presence of threatened and ecologically sensitive species highlights the **moderate to high conservation value of the river system**, particularly in downstream reaches where habitat heterogeneity is greater.

Table 28: Seasonal comparison of fish diversity and abundance recorded during the surveys for the Bunakha HPP

Parameter	Pre-Monsoon	Monsoon	Post-Monsoon
Number of Species	2	28	12
Total Individuals	Low (<50)	241	195
Dominant Species	*Schizothorax richardsonii*, *Salmo trutta*	*Neolissochilus hexagonolepis*, *Opsarius barna*	*Neolissochilus hexagonolepis*, *Schizothorax richardsonii*
Shannon Index (H′)	Low (~0–0.5)	High (0–3.16)	Moderate (0–1.15)
Ecological Condition	Stable (Low Flow)	Disturbed (High Flow)	Recovery Phase

Macroinvertebrates and Plankton Communities

Macroinvertebrate and plankton communities provide important indicators of ecological health and water quality:

- Pre-monsoon: Moderate diversity (16–24 macroinvertebrate families), stable conditions
- Monsoon: Highest diversity (26 families), dominated by flow-tolerant taxa (e.g., Baetidae ~48%)
- Post-monsoon: Reduced but recovering diversity (12 families), indicating system stabilization

Plankton communities (phytoplankton, periphyton, and zooplankton) across all seasons are dominated by:

- Diatoms and green algae (indicative of moderate nutrient levels)
- Stable assemblages suggesting low pollution and good ecological balance

Table 29: Seasonal comparison of macroinvertebrate diversity recorded during the surveys for the Bunakha HPP

Parameter	Pre-Monsoon	Monsoon	Post-Monsoon
Number of Families	16–24	26	12
Dominant Group	Mixed taxa	Baetidae (~48%)	Mixed recovery taxa
Ecological Indication	Stable conditions	Flow disturbance	Recovery and stabilization

7.2.1.3 Water Quality (Biodiversity-relevant Parameters)

Physicochemical parameters across all three seasons indicate consistently good water quality, suitable for aquatic life:

- Temperature: ~10°C to 21.6°C
- pH: ~6.8 to 8.56

- Dissolved Oxygen: ~7.8 to 12.5 mg/L
- Low nutrient and pollutant concentrations

These results confirm that the Wangchu River remains largely unpolluted, with only localized disturbances near infrastructure or modified sections.

Table 30: Water quality (biodiversity-relevant parameters) recorded during the surveys for the Bunakha HPP

Parameter	Range Observed	Interpretation
Temperature	10–21.6°C	Suitable for cold-water species
pH	6.8–8.56	Within acceptable limits
Dissolved Oxygen	7.8–12.5 mg/L	High oxygen availability
Turbidity	Variable (higher in monsoon)	Sediment-driven seasonal change
Nutrients	Low	Low anthropogenic influence

7.2.1.4 Ecological Interpretation

The integrated seasonal assessment indicates that:

- The river maintains good ecological integrity across seasons
- Hydrological variability is the primary driver of ecological dynamics
- The system supports important native and threatened fish species
- Habitat heterogeneity increases downstream of the Bunakha HPP, enhancing biodiversity
- No evidence of severe ecological degradation or critical habitat fragmentation is observed

However, localized pressures are identified:

- Flow regulation from upstream HPPs
- Sediment fluctuations during monsoon
- Reduced habitat complexity in regulated reaches may influence ecological conditions at specific sites.

The Wangchu River within the Bunakha HPP AoI represents a **functionally intact mountain river ecosystem with seasonal variability but overall ecological resilience**. The presence of conservation-significant species and good water quality underscores the importance of maintaining ecological flows and minimizing habitat alteration during Project development.

7.2.2 Terrestrial Biodiversity

7.2.2.1 Vegetation and Habitat Characteristics

The vegetation within the Project's AoI is representative of mid-Himalayan Forest ecosystems, characterized by a mosaic of broadleaf forests, blue pine stands, mixed conifer forests, shrubland, and meadow habitats. These habitat types are distributed along elevation gradients and topographic variations, resulting in diverse vegetation structure and composition across the study area. Broadleaf forests form the dominant habitat, supporting relatively higher species richness and structural complexity compared to other habitat types.

Vegetation surveys conducted across multiple seasons recorded a total of 45 tree species, indicating moderate floral diversity and ecological integrity. Variations in species composition, basal area, and density were observed across sampling plots.

Importance Value Index (IVI) analysis highlights the **dominance of characteristic native species** within each habitat type, reflecting relatively stable ecological conditions in undisturbed areas. However, localized modifications were observed in areas influenced by anthropogenic activities such as access roads, settlements, and previously disturbed slopes, where vegetation structure is comparatively altered.

Screening using IBAT and IUCN datasets identified the presence of plant species of conservation significance within the broader landscape, although **no critical habitat-triggering plant species were confirmed** within the immediate project footprint.

The overall vegetation condition suggests a **Natural Habitat** with moderate sensitivity, where ecological value is primarily derived from habitat diversity, forest continuity, and associated ecosystem functions rather than the presence of rare or endemic plant species at site level. A detailed list of recorded plant species, along with their conservation status, is provided in 0.

7.2.2.1.1 Invasive plant species

Invasive plant species recorded within the Project area are primarily associated with disturbed habitats such as road corridors, construction-prone areas, and degraded forest edges.

A total of 25 invasive plant species were recorded during the surveys. Key invasive species include *Ageratina adenophora*, *Chromolaena odorata*, *Lantana camara*, and *Mikania micrantha*, which are widely recognized for their aggressive colonization and potential to outcompete native vegetation.

The distribution of invasive species is currently localized and limited in extent, indicating **that intact forest habitats remain largely unaffected**. However, these species demonstrate a strong association with anthropogenic disturbance and may expand during construction activities due to soil disturbance and increased accessibility.

No large-scale invasive species infestation was observed within intact forest habitats; however, disturbed areas present potential hotspots for future spread. Therefore, appropriate management measures, including restoration with native species and monitoring of disturbed areas, will be necessary to minimize the risk of invasive species proliferation.

A detailed list of recorded invasive plant species, including scientific name, is provided in 0.

No dedicated standalone Invasive Species Management Plan has been prepared; however, invasive species prevention, control, and monitoring measures are comprehensively integrated across multiple existing ESMP sub-plans.

The key provisions addressing invasive species across the ESIA are as follows:

- ESMP Construction Phase — IESC#11 (Table 61).
- ESMP Operation Phase — IESC#11 (Table 65).
- Greenbelt Development Plan (Section 13.5.6).
- Biodiversity conservation and wildlife management plan (section 13.54)

These measures address the full prevention, control monitoring cycle recommended for invasive species management.

7.2.2.2 Terrestrial Mammals

Mammal surveys recorded a total of 10 mammal species, representing typical fauna of mid-Himalayan Forest ecosystems. The recorded species include a combination of forest-dependent, generalist, and wide-ranging species, utilizing diverse habitat types such as broadleaf forests, mixed forests, and riparian corridors. The recorded assemblage includes species of conservation importance such as *Cuon alpinus* (EN) and *Ursus thibetanus* (VU).

Field observations, including direct sightings and indirect evidence (tracks, scats, and signs), indicate that mammals are primarily associated with intact forest habitats and riverine corridors, which serve as important movement pathways within the landscape. Larger mammals and elusive species were mostly detected through indirect signs, reflecting their cryptic behavior and low detectability during field surveys.

Screening using IBAT and IUCN datasets indicates the presence of species of conservation significance within the broader landscape, although **no confirmed critical habitat-triggering species were recorded** within the immediate project footprint. The Project area contributes to landscape-level habitat connectivity, particularly along forested slopes and river corridors, which are important for wildlife movement.

Overall, mammalian diversity within the AoI is assessed as moderate, with ecological sensitivity primarily linked to habitat continuity and disturbance levels rather than species concentration. With appropriate mitigation measures, Project-related impacts on mammals are expected to be localized and manageable.

A detailed list of recorded mammal species, including conservation status and observation type, is provided in 0.

7.2.2.3 Avifauna (Birds)

Avifaunal surveys conducted across multiple seasons recorded a total of 97 bird species within the Project AoI, reflecting the ecological diversity of the mid-Himalayan landscape. The recorded assemblage includes a mix of resident, migratory, and habitat-specialist species, occupying a range of habitats such as broadleaf forests, mixed forests, riparian zones, and open areas. The recorded avifauna includes riverine indicator species such as *Cinclus pallasii* and *Megaceryle lugubris*, reflecting good ecological condition of aquatic–terrestrial interface habitats.

Bird diversity was observed to be highest in broadleaf and mixed forest habitats, which provide suitable nesting, foraging, and shelter conditions. Seasonal variation influences bird activity and detectability, with increased diversity and vocal activity during the monsoon and post-monsoon periods. Riparian areas and forest edges also support a variety of species due to increased habitat heterogeneity.

IBAT screening identified bird species of conservation importance within the wider landscape, including species with potential relevance for critical habitat assessment. However, **no confirmed nesting sites or congregation areas of critical importance were recorded** within the immediate

project footprint. The AoI therefore functions as part of a broader ecological landscape supporting avifaunal diversity, rather than a site of critical habitat concentration.

Overall, avifaunal diversity is assessed as moderate to high, with ecological sensitivity linked to habitat quality, forest cover, and disturbance levels. Project-related impacts on avifauna are expected to be limited and site-specific, provided appropriate mitigation measures are implemented.

A comprehensive checklist of bird species recorded during the surveys, including conservation status and habitat association, is provided in 0.

7.2.2.4 Herpetofauna

A total of 28 herpetofauna species were recorded within the Project area during surveys, comprising 25 reptile species and 3 amphibian species. Reptiles are dominated by snake species (17 species), followed by lizards (7 species) and one single turtle species (*Indotestudo elongata*) recorded. The presence of species such as *Indotestudo elongata* (EN) highlights **localized conservation value**, although overall sensitivity remains moderate. Amphibians are represented by species belonging to the *Bufonidae* and *Dicroglossidae* families.

Amphibian surveys were not conducted during the pre-monsoon season due to unfavorable dry conditions and were not repeated in the post-monsoon season, as the monsoon period represents the most suitable time for detection. Therefore, the monsoon dataset provides the primary and most representative baseline for amphibian diversity within the Project area.

Herpetofaunal observations indicate strong seasonal variation, with amphibians primarily recorded during the monsoon (S2), while reptiles were observed across all seasons with higher representation in pre-monsoon (S1) and post-monsoon (S3) surveys. A detailed list of recorded herpetofauna species, including scientific name and conservation status, is provided in 0.

7.2.2.5 Seasonal Terrestrial Biodiversity Patterns

Seasonal variation in the Project area reflects natural ecological cycles governed by climatic conditions and vegetation dynamics. The monsoon period enhances primary productivity and increases biodiversity activity, while the post-monsoon phase is characterized by ecological stabilization and maturity of habitat conditions. Overall, the terrestrial ecosystem follows a clear seasonal pattern of baseline stability, climatic influence, and subsequent ecological recovery, indicating a resilient and functionally intact system.

Observed seasonal differences primarily influence species detectability rather than actual species presence, with **post-monsoon surveys providing the most representative baseline of biodiversity**. Broadleaf and mixed forest habitats contribute substantially to overall biodiversity value and serve as key habitats for wildlife, underscoring the ecological significance of the project landscape.

Table 31: Seasonal Biodiversity Patterns in the Bunakha HPP's AoI

Component	Pre-Monsoon	Monsoon	Post-Monsoon
Vegetation	Stable baseline	Peak growth and density	Mature structure and stability

Component	Pre-Monsoon	Monsoon	Post-Monsoon
Mammals	Moderate activity	Reduced visibility	Increased detectability
Birds	Moderate diversity	High activity/diversity	Stable community
Herpetofauna	Low	Moderate (moist conditions)	Moderate
Invasive Species	Low presence	Slight spread in disturbed areas	Stabilized

7.2.3 Protected and Conservation Areas

The Bunakha HPP is situated within a landscape of significant biodiversity value, in proximity to several nationally and internationally recognized protected areas, biological corridors, and Key Biodiversity Areas (KBAs).

An assessment of conservation sites within a 50 km radius from the Project dam reveals the presence of two protected areas - Jigme Dorji National Park and Jigme Khesar Strict Nature Reserve, two biological corridors (BC-1 and BC-2) and multiple KBAs, including Kamji, Paro Wetlands, Chele La, Samtse, Thimphu wetlands, Ada Lake / Puna Tsangchu, and Dochu La (Table 32 and Figure 33).

Table 32: Protected areas, biological corridors, KBAs and IBAs surrounding the Bunakha HPP's AoI

Type	Name	Aerial Distance from Bunakha Dam						IUCN Category	Status	Lies within	
		1 km	10 km	20 km	30 km	40 km	50 km			AoI*	EAAA**
Protected Area	Jigme Dorji National Park	No	No	No	No	No	Yes	II	Designated	No	No
	Jigme Khesar Strict Nature Reserve	No	No	No	No	Yes	Yes	Ia	Designated	No	No
Biological Corridor (BC)	BC-1	No	No	No	No	No	Yes	VI	Designated	No	No
	BC-2	No	No	No	Yes	Yes	Yes	VI	Designated	No	**Yes**
KBAs/IBAs	Kamji	No	No	No	Yes	Yes	Yes	-	Designated	No	**Yes**
	Paro Wetlands	No	No	No	Yes	Yes	Yes	-	Designated	**Yes*** **	**Yes**
	Chele La	No	No	No	Yes	Yes	Yes	-	Designated	No	**Yes**

Type	Name	Aerial Distance from Bunakha Dam						IUCN Category	Status	Lies within	
		1 km	10 km	20 km	30 km	40 km	50 km			AoI*	EAAA**
	Samtse	No	No	No	No	Yes	Yes	-	Designated	No	No
	Toorsa Strict Nature Reserve	No	No	No	No	Yes	Yes	-	Designated	No	No
	Thimphu wetlands	No	No	No	No	Yes	Yes	-	Designated	No	No
	Jigme Dorji National Park	No	No	No	No	No	Yes	-	Designated	No	No
	Ada lake / Puna Tsangchu	No	No	No	No	No	Yes	-	Designated	No	No
KBA	Dochu La	No	No	No	No	No	Yes	-	Designated	No	No
Ramsar Site	-	No	No	No	No	No	No	-	No	No	No
World Heritage Site	Bhutan does not currently have any UNESCO World Heritage Sites										
Alliance for Zero Extinction (AZE)	Bhutan does not currently have any Alliance of Zero Extinction										

*AoI: Area of Influence - see Chapter 4.2- The AoI was delineated by applying a 5 and 10 km buffer around the Project's main components

**EAAA: Ecologically Appropriate Areas of Assessment / Analysis (EAAAs) - see Chapter 7.2.5.3. The buffer zones for the Critical Habitat Assessment are centered only at the dam location, with distances matching precisely.

*** Paro Wetland does not fall under the Direct AoI and fall under Indirect AoI.

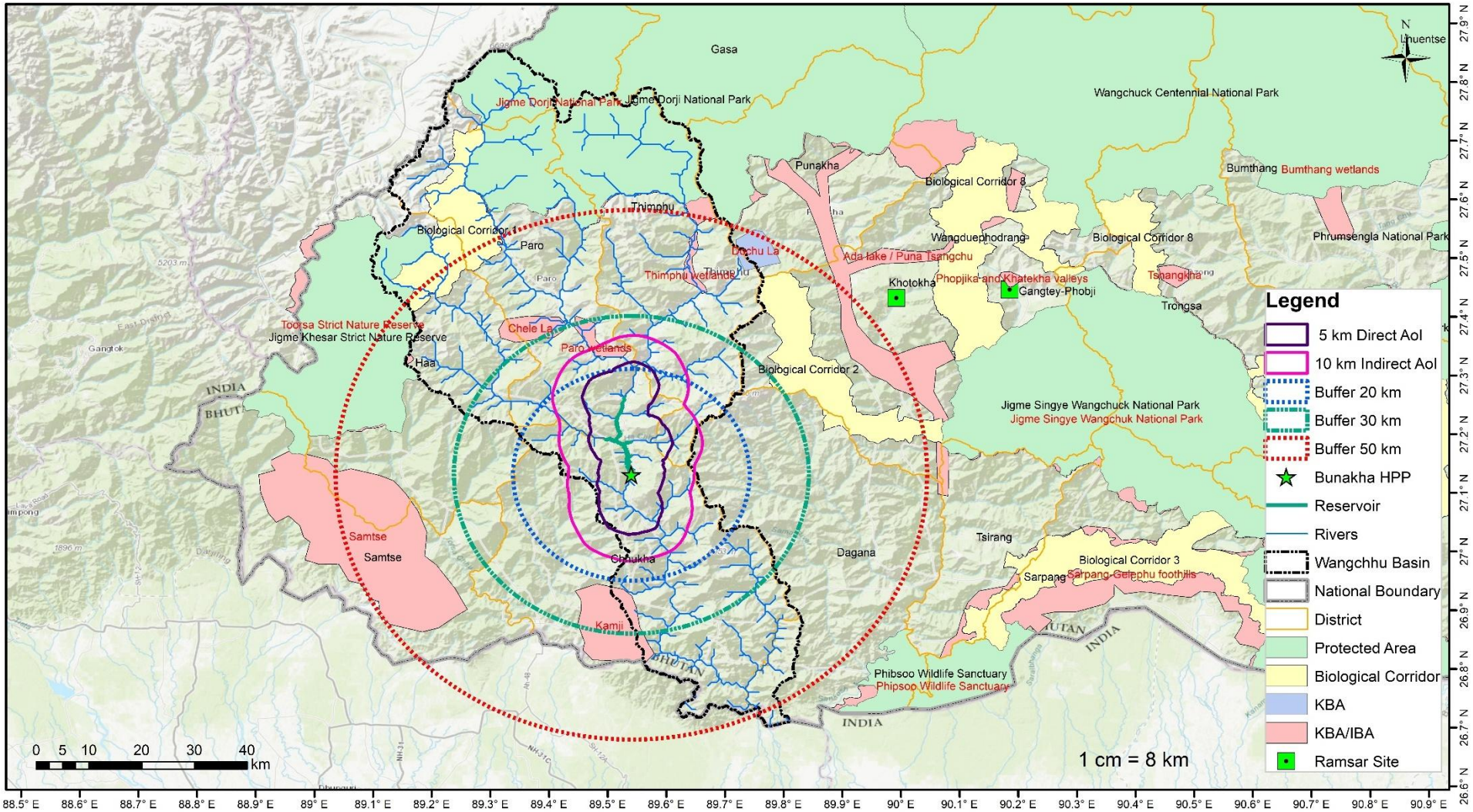


Figure 33: Protected areas, biological corridors, KBAs and IBAs surrounding the Bunakha HPP's AoI

7.2.3.1 Protected Areas

Jigme Dorji National Park (JDNP)

Jigme Dorji National Park (JDNP) is located within 50 km aerial distance from the Bunakha dam. It is the second largest national park in Bhutan, covering an area of 4,316 km² (431,600 ha) in the northwestern part of the country, sharing an international border with the Tibet Autonomous Region of China. Established in 1974 as a wildlife sanctuary in memory of the Third King, it was upgraded to a national park in 1993.

JDNP is renowned for its outstanding biodiversity and is the only park in the world where the Royal Bengal Tiger (*Panthera tigris tigris*) and the Snow Leopard (*Uncia uncia*) coexist, with tigers recorded at altitudes up to 4,200 masl - the highest documented in any tiger range country. It is the only park in Bhutan where the largest population of the Bhutan Takin (*Budorcas taxicolor whitei*), the national animal, thrives, and it is the only protected area in the country where all four national symbols - Takin (animal), Raven (bird), Blue Poppy (flower), and Cypress (tree) - are found together.

This Park serves as the watershed for four major rivers of western Bhutan - Pachhu, Wangchhu, Phochhu, and Mochhu - and supports four major ecosystems: warm broadleaf forest, cool broadleaf forest, mixed coniferous forest, and alpine meadows. It is home to more than 36 mammal species, 328 bird species, 39 butterfly species, 5 reptile species, and 300 medicinal plant species.

The Park is managed by the Department of Forests and Park Services, with a dedicated team addressing challenges such as human-wildlife conflict, unsustainable resource use, and illegal wildlife trade.

Jigme Khesar Strict Nature Reserve (JKSNR)

Jigme Khesar Strict Nature Reserve (JKSNR) is located within 40 km aerial distance from the Bunakha dam. It is the only Strict Nature Reserve declared by the Royal Government of Bhutan, initially established as the Toorsa Strict Nature Reserve in 1993 and coming into operation in 2010. In October 2014, it was renamed in honor of His Majesty the King Jigme Khesar Namgyel Wangchuck for his extraordinary contributions to environmental protection and conservation. The reserve covers an area of 784.225 km², encompassing a range of habitat zones from tropical broadleaved forest in the south to alpine ecosystems in the north.

It is the only protected area in Bhutan without permanent human settlements, except for a few migratory yaks herding communities, making it virtually uninhabited and one of the most pristine temperate and alpine landscapes in the entire Himalayas.

It is home to numerous endemic and threatened species, including Tiger (*Panthera tigris tigris*), Snow Leopard (*Panthera uncia*), Red Panda (Ailurus fulgens), Alpine Musk Deer (*Moschus chrysogaster*), Bhutan Takin (Budorcas taxicolor whitei), Asiatic Black Bear (*Ursus thibetanus*), and endemic plant species such as *Meconopsis superba* and *Bhutanthera himalayana* found in the northern part of the reserve.

JKSNR has documented 754 plant species, including 205 trees and shrubs, 193 herbs and grasses, and 112 orchids; along with 42 mammal species, 236 bird species, 71 butterflies, 17

reptiles, and 7 fish species. Among these, the reserve hosts 4 endangered species, 7 vulnerable species, 9 near-threatened species, 19 least concern species, and 11 species listed under Schedule I of the Forest and Nature Conservation Act of Bhutan.

7.2.3.2 Biological corridors

Biological Corridor 1 (BC-1)

The Biological Corridor 1 (BC-1) connecting Jigme Dorji National Park (JDNP) and Jigme Khesar Strict Nature Reserve (JKSNR) is located within 50 km aerial distance from the Bunakha dam. The corridor was established in 1999 and covers an area of 255.55 km², spanning three eastern districts of Bhutan. The corridor is managed by the Divisional Forest Office in Paro Dzongkhag.

BC-1 includes Bjee Gewog in Haa district, comprising nine chiwogs. The corridor supports five distinct forest types: Juniper Forest, Fir Forest, Spruce Forest, Hemlock Forest, and Blue Pine Forest. It is an important habitat for several globally significant bird species, including the Vulnerable Wood Snipe (*Gallinago nemoricola*), the globally Near Threatened Satyr Tragopan (*Tragopan satyra*), and the Himalayan Monal (*Lophophorus impejanus*), which is a totally protected bird species under the Forest and Nature Conservation Act. The presence of restricted-range species such as the Hoary-throated Barwing (*Actinodura nipalensis*) and significant high-altitude birds like the Snow Partridge (Lerwa lerwa) has also been recorded. BC-1 also host Tiger, Snow Leopard, Takin, Asiatic Golden Cat (*Catopuma temminckii*), Leopard Cat (*Prionailurus bengalensis*), and Common Leopard (*Panthera pardus*). Additionally, the corridor has been identified as a summer habitat for Takin.

Biological Corridor 2 (BC-2)

BC-2, located at a 40 km aerial distance from the Bunakha dam, was established in 1999 and covers an area of 291.76 km², running through Wangdue Phodrang and part of Thimphu Dzongkhags. The corridor connects Jigme Singye National Park and Royal Botanical Park, Lamperi, and is managed by the Wangdue Divisional Forest Office. It serves Daga, Gasetsho Wogm, Gasetsho Gogm gewogs, and Nahi chiwogs under Wangdue Dzongkhag.

The corridor encompasses a range of habitats from subtropical to temperate climates and provides safe havens for rare and endangered animals, including Tiger, Red Panda, Musk Deer, Clouded Leopard, Rufous-necked Hornbill, and so on.

7.2.3.3 Key Biodiversity Areas (KBAs) / Important Birds and Biodiversity Areas (IBAs)

Kamji KBA/IBA

Kamji, also known as Khamjii, is located in Chhukha District, Bhutan, and is recognized as a Key Biodiversity Area (KBA) and an Important Bird and Biodiversity Area (IBA). Covering approximately 140 km² at elevations ranging from 700 to 1,500 meters, it is situated at the transition zone between subtropical and temperate forests. The site meets IBA criteria A1 and A3. It is of particular conservation significance for harboring globally threatened species, including the endangered Rufous-necked Hornbill (Aceros nipalensis), which is associated with high-altitude forest habitats.

Paro Wetlands KBA

Paro Wetlands is a designated Key Biodiversity Area (KBA) recognized for its conservation significance as part of the global KBA network. It is partially included in the Project's indirect AoI. The site is known to support the Wood Snipe (*Gallinago nemoricola*), a globally vulnerable bird species (IUCN Red List Category: VU), recorded in the area in 2005. A

Chele La KBA

Chele La, located approximately 30 km away from the Bunakha dam, is a designated KBA recognized for its conservation significance as part of the global KBA network. Just like the Paro Wtlands KBA, the Chele La KBA is known to support the Wood Snipe (*Gallinago nemoricola*), a globally vulnerable bird species (IUCN Red List Category: VU), recorded in the area in 2005.

Samtse KBA

Samtse, located approximately 40 km away from the Bunakha dam, is a designated KBA, recognized for its conservation significance as part of the global KBA network. The site is known to support the Rufous-necked Hornbill (*Aceros nipalensis*), a globally vulnerable bird species (IUCN Red List Category: VU), recorded in the area in 2005.

Thimphu wetlands KBA

Thimphu Wetlands, located approximately 40 km away from the Bunakha dam, is a designated KBA recognized for its conservation significance as part of the global KBA network. The site is known to support the Wood Snipe (*Gallinago nemoricola*), a globally vulnerable bird species (IUCN Red List Category: VU), recorded in the area in 2005.

Ada lake / Puna Tsangchu KBA

Ada Lake / Puna Tsangchu form a designated KBA located approximately 50 km away from the Bunakha dam, with a confirmed KBA status based on the 2005 assessment. Covering an area of approximately 365.4 km², the site encompasses a mix of freshwater and terrestrial systems, with elevations ranging from 200 to 2,000 meters.

Habitats within the KBA are equally divided between forest (50%) and inland wetlands (50%). The site is known to support several globally threatened bird species, including the Endangered White-bellied Heron (*Ardea insignis*), the Vulnerable Pallas's Fish-eagle (*Haliaeetus leucoryphus*) and Grey-crowned Prinia (*Prinia cinereocapilla*), as well as the Ruddy Shelduck (*Tadorna ferruginea*), which is listed as Least Concern.

Dochu La KBA

Dochu La KBA is one of Bhutan's most scenic and culturally revered mountain passes, situated along the road between Thimphu and Punakha. Surrounded by dense forests of rhododendron and dwarf bamboo, the pass holds deep spiritual and cultural significance and serves as a popular stop for travelers seeking to appreciate the serene highland landscape.

7.2.4 Ecosystem services

Ecosystem services are the benefits that people obtain from ecosystems and can broadly be categorized into four groups:

- Provisioning services
- Regulating services
- Cultural services
- Supporting services

The ecosystem services identified in the Project area are closely linked with the biodiversity resources described in the biological baseline assessment (Chapters 7.2.1 to 7.2.3) and provide important benefits for local communities and ecosystem functioning.

The assessment of ecosystem services in the Project area follows internationally recognized frameworks such as the Millennium Ecosystem Assessment, 2005 and aligns with good international industry practice (GIIP) for hydropower ESIA and with safeguard principles under Asian Development Bank Safeguard Policy Statement (2009).

Ecosystem services were identified through field observations, consultations with local communities (April, July and December 2025), and review of baseline ecological and socio-economic information collected during the ESIA study.

The primary beneficiaries of ecosystem services in the Project area are:

- Local farming households
- Livestock owners
- Forest-dependent communities
- Religious institutions and local residents
- Visitors to cultural and scenic sites

7.2.4.1 Provisioning Ecosystem Services

Provisioning services refer to the material products obtained from ecosystems such as food, timber, water, and other natural resources that support local livelihoods.

Agricultural Production/ Arable Land

Agricultural lands within the Project area provide important provisioning ecosystem services in the form of crop production, fruit cultivation, and vegetable farming. Local communities cultivate crops and fruits primarily for household consumption, while vegetables are both consumed locally and sold in nearby markets. Kitchen gardens and small orchards are also common within the Project area.

Grazing Resources

Livestock raising, particularly cattle for dairy production, forms an important component of local livelihoods. Forest edges, open areas, and State Reserved Forest lands within the project area provide grazing ecosystem services for livestock.

Aquatic Resources

The river system within the Project area provides aquatic ecosystem services including habitat for fish and other aquatic organisms. Although fishing activities are limited and generally require permits, some residents may occasionally fish for subsistence purposes.

Timber Resources

Direct dependence on timber was not explicitly identified in RP surveys. Therefore, timber provisioning is recognized as a *potential* ecosystem service based on regional forest use practices, rather than a confirmed primary livelihood dependency.

In the sense of the above, forests within the Project area provide timber resources that may be used in local construction and household needs. Communities may collect timber from community forests in accordance with local forest management regulations. Timber extraction is generally regulated and controlled through local forest management systems.

Non-Timber Forest Products

Local communities collect a variety of non-timber forest products (NTFPs) including mushrooms, ferns, edible wild vegetables, medicinal plants, and forest fruits. Specific dependence on NTFPs was not strongly evidenced in RP or socio-economic surveys, but is considered a potential supplementary ecosystem service based on regional practices.

These resources, when used, may contribute to household nutrition and provide supplementary income through local markets.

Both the community dependence up and downstream of the river as a direct livelihood resource is minimal. Field surveys and stakeholder consultations indicate that households in Bunakha and Chanachen Chiwogs rely primarily on tributary streams and seasonal channels for drinking water and irrigation rather than the main river itself; therefore, potential changes in river water quality or morphology resulting from reservoir operation are unlikely to have significant direct impacts on local livelihoods. Similarly, collection of non-timber forest products (NTFPs) within the proposed submergence area is limited, with most harvesting occurring in forest areas outside the inundation zone, resulting in negligible impacts on household use of these resources.

It is further noted that Human-Wildlife Conflict has been an existing challenge in Chanachen Chiwog, addressed through the installation of an approximately 5 km chain-link fence enclosing the village, partly funded and contributed by the community itself. This existing mitigation infrastructure demonstrates that HWC is a pre-existing condition actively managed at the community level, independent of the Project.

7.2.4.2 Regulating Ecosystem Services

Regulating ecosystem services refer to natural processes that regulate environmental conditions such as erosion control, water regulation, and climate regulation.

Soil Stabilization and Erosion Control

Forest vegetation within the Project area plays an important role in stabilizing slopes, reducing soil erosion, and retaining sediments. These services are particularly important in mountainous terrain where vegetation cover helps reduce landslide risks and protect downstream water quality.

Water Regulation

Forest and riparian ecosystems contribute to the regulation of surface water flows by enhancing infiltration, reducing runoff, and maintaining water quality. These ecosystem services help regulate seasonal water flows and support the health of river ecosystems.

Climate Regulation

Forest ecosystems within the Project area store carbon in vegetation and soils, contributing to climate regulation services.

7.2.4.3 Cultural Ecosystem Services

Cultural ecosystem services include spiritual, religious, heritage, and aesthetic values associated with landscapes and ecosystems.

Religious and Spiritual Sites

The project area contains several culturally significant locations that provide important cultural ecosystem services, particularly spiritual and religious values for local communities.

- Bunakha Lhakhang, a prominent temple situated on the eastern riverbank near the main access road, represents an important religious site for residents.
- Lamche Bja (Elephant Cliff) is a spiritually revered cliff located upslope from the proposed quarry area. Local communities have expressed concerns

Cultural Landscape and Heritage Sites

Several culturally sensitive locations are situated within the wider project landscape.

- Lobnekha Heritage Village located approximately 3–4 km north-northeast of the main project activity zone, lies downwind of the project area.
- Similarly, Nayatsen and Tsho Sacred Sites and Geling Goenpa Monastery, located northwest of the project site, occur within areas characterized by relatively quiet soundscapes and clean air conditions.

Aesthetic and Ecosystem Services

The river valley and surrounding forested landscapes provide aesthetic ecosystem services that contribute to the scenic quality of the area.

Recreational Ecosystem Services

The proposed reservoir, approximately 17 km in length, may create opportunities for recreational ecosystem services such as boating, bird watching, and catch-and-release fishing.

However, DGPC plans to study the feasibility of installing floating solar PV systems on the reservoir, which may limit available areas for recreation.

7.2.4.4 Supporting Ecosystem Services

Forest and river ecosystems within the Project area provide supporting ecosystem services that underpin biodiversity and ecological productivity. These include habitat provision for terrestrial and aquatic species, nutrient cycling, and maintenance of ecosystem processes that sustain local biodiversity.

7.2.5 Critical habitats

Critical habitat (CH), as defined in ADB's Safeguard Policy Statement (SPS, 2009) is a subset of both natural and modified habitats that includes areas with high biodiversity value and deserves particular attention, including:

- Habitat required for the survival of critically endangered or endangered species
- Areas having special significance for endemic or restricted-range species
- Sites that are critical for the survival of migratory species.
- Areas supporting globally significant concentrations or numbers of individuals of congregatory species
- Areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services
- Areas having biodiversity of significant social, economic, or cultural importance to local communities.

The SPS also states that CHs include those areas either legally protected or officially proposed for protection, such as areas that meet the criteria of the World Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization's World Natural Heritage sites.

7.2.5.1 Requirements for project development in CH

According to ADB SPS, no project activity will be implemented in areas of CH unless the following requirements are met:

- There are no measurable adverse impacts, or likelihood of such, on the CH which could impair its high biodiversity value or the ability to function.
- The project is not anticipated to lead to a reduction in the population of any recognized endangered or critically endangered species or a loss in area of the habitat concerned, such that the persistence of a viable and representative host ecosystem be compromised.
- Any lesser impacts are mitigated.

In a CH, mitigation measures will be designed to achieve at least no net loss of biodiversity. They may include a combination of actions, such as post-project restoration of habitats, offset of losses through the creation or effective conservation of ecologically comparable areas that are managed for biodiversity while respecting the ongoing use of such biodiversity by Indigenous Peoples or traditional communities, and compensation to direct users of biodiversity.

Also, in circumstances where some project activities are located within a legally protected area, in addition to the requirement specified above, the borrower/client will meet the following requirements:

- Act in a manner consistent with defined protected area management plans.
- Consult protected area sponsors and managers, local communities, and other key stakeholders on the proposed project.
- Implement additional programs, as appropriate, to promote and enhance the conservation aims of the protected area.

7.2.5.2 Critical Habitat Screening

The screening of 2,020 species indicated the likely presence of twenty-five (26) CH-qualifying/candidate species within the Bunakha HPP's EAAAs, of which:

- two (2) critically endangered (CR) species of birds
- five (5) endangered (EN) species:
  - three (3) mammals
  - one (1) flowering plant
  - and one (1) fish
- two (2) vulnerable (VU) species of plants
- two (2) near-threatened (NT) species:
  - one (1) bird
  - one (1) plant
- twelve (12) least-concern (LC) species:
  - nine (9) birds
  - one (1) plant
  - one (1) fish
  - one (1) insect
- three (3) data-deficient (DD) species:
  - two (2) insects
  - one (1) amphibian.

7.2.5.3 Critical Habitat Assessment

Ecologically Appropriate Areas of Assessment (EAAAs)

The concept of Ecologically Appropriate Areas of Assessment / Analysis (EAAAs) is directly or indirectly considered under several environmental safeguards from international development banks, including the ADB. In sum, the EAAAs are understood as the spatial areas that are ecologically relevant for assessing the presence and viability of biodiversity features that may trigger critical habitat designation.

EAAAs are most commonly based on habitat boundaries, catchments, or altitudinal limits, as relevant to specific species. In all cases, EAAAs should at minimum be large enough to encompass all potential direct and indirect project impacts on the species concerned.

For the Bunakha HPP, a precautionary boundary was delineated for each trigger species to define the Ecologically Appropriate Area of Assessment (EAAA). This boundary captures Area of Influence (direct, indirect, and cumulative), habitat requirements and connectivity associated to the species. The approach ensured that all areas necessary to meet the ecological requirements of the species were adequately encompassed within the assessment

Areas of Habitat (AOHs)

An Area of Habitat (AOH) is the portion of a species' geographic range that is actually suitable and available for it to occupy, based on its ecological requirements. Within Bunakha HPP's EAAAs, the AOHs were delineated for each screened species, taking into account ecological factors such as elevation, land use, climate, proximity to water, and/or human disturbance.

Table 33: EAAAs and AOHs for terrestrial and aquatic species

Biodiversity Group	Name of Species (GROUP)	EAAA	AOH (km^2)
Resident species with small home ranges (e.g., arthropods, amphibians); and Vegetation	*Corallodiscus cooperi* (MAGNOLIOPSIDA)	10 km buffer from the Project construction sites / Terrestrial AoI	EAAA
	Drepanostachyum annulatum (LILIOPSIDA)		EAAA
	Strobilanthes accrescens subsp. accrescens (MAGNOLIOPSIDA)		EAAA
	Carex speciosa subsp. pinetorum (LILIOPSIDA)		EAAA
	Cephalaeschna triadica (INSECTA)		27
	Coeliccia svihleri (INSECTA)		EAAA
	Duttaphrynus nagalandensis (AMPHIBIA)		EAAA
	Megalestes Irma (INSECTA)		EAAA
	Pedicularis amplicollis (MAGNOLIOPSIDA)		EAAA
Migratory species and Resident species with large home ranges	*Ailurus fulgens* (MAMMALIA)	20 km buffer from Project construction sites	1672
	Cuon alpinus (MAMMALIA)		2071
	Aegithalos iouschistos (AVES)		1032
	Apus acuticauda (AVES)		39
	Certhia discolor (AVES)		742
	Certhia nipalensis (AVES)		2098
	Harpactes wardi (AVES)		0.63
	Myzornis pyrrhoura (AVES)		1732
	Prinia atrogularis (AVES)		985
	Tragopan satyra (AVES)		1563
	Zoothera salimalii (AVES)		1533
	Pteruthius flaviscapis (AVES)		NA
Migratory and water dependent species	*Ardea insignis* (AVES)	20 km buffer from the Project construction sites and lower part of Wangchu basin	283

Biodiversity Group	Name of Species (GROUP)	EAAA	AOH (km^2)
	Tor putitora (ACTINOPTERYGII)	10 km buffer from the Project construction site and lower part of Wangchu basin	276
	Chagunius chagunio (ACTINOPTERYGII)	10 km buffer from the Project construction site and lower part of Wangchu basin	391
Animals with very large home range	*Gyps bengalensis* (AVES)	30 km buffer from the Project construction sites	559
	Panthera tigris (MAMMALIA)		3082

Conclusions

A total of 2,020 species (terrestrial and aquatic) were assessed against Critical Habitat (CH) Criteria 1–3 for the BHPP. Of these, **six species** meet the Critical Habitat criteria (Table 34).

Table 34: Species meeting Critical Habitat criteria 1-3 and thresholds

S . No.	Group	Common Name	Scientific Name
1	Aves	White-bellied Heron	*Ardea insignis*
2	Magnoliopsida	-	*Drepanostachyum annulatum*
3	Liliopsida	-	*Strobilanthes accrescens subsp. accrescens*
4	Liliopsida	-	*Carex speciosa subsp. pinetorum*
5	Insecta	-	*Cephalaeschna triadica*
6	Magnoliopsida	-	*Pedicularis amplicollis*

Additionally, two KBAs/IBAs, the **Kamji IBA/KBA** and **Paro Wetland KBA/IBA**, qualify under Critical Habitat Criterion 6.

No species associated with key evolutionary processes or providing critical ecosystem services (CH Criterion 4), or of notable social, economic, or cultural importance to local communities (CH Criterion 5) were identified.

During the assessment, some species were identified that, while not formally meeting Critical Habitat thresholds, occur close to threshold criteria. In addition, certain species are of recognized cultural and socio-economic importance to local communities (Table 35).

Table 35: Near-threshold, and socio-economically and culturally significant species

S. No.	Group	Common Name	Scientific Name
1	Aves	Rufous-necked Hornbill	*Aceros nipalensis*
2	Mammalia	Red Panda	*Ailurus fulgens*

S. No.	Group	Common Name	Scientific Name
3	Mammalia	Dhole	*Cuon alpinus*
4	Mammalia	Tiger	*Panthera tigris*
5	Actinopterygii	Golden Mahseer	*Tor putitora*
6	Aves	Rufous-fronted Tit	*Aegithalos iouschistos*
7	Aves	Fire-tailed Myzornis	*Myzornis pyrrhoura*
8	Aves	Black-throated Prinia	*Prinia atrogularis*
9	Aves	Satyr Tragopan	*Tragopan satyra*
10	Aves	Himalayan Forest Thrush	*Zootera salimalii*

7.3 Human Environment

7.3.1 Project districts/Dzongkhags

The Bunakha HPP is located in the Chhukha district/ Dzongkhag. The head of the reservoir borders the Paro district/ Dzongkhag (Figure 34).

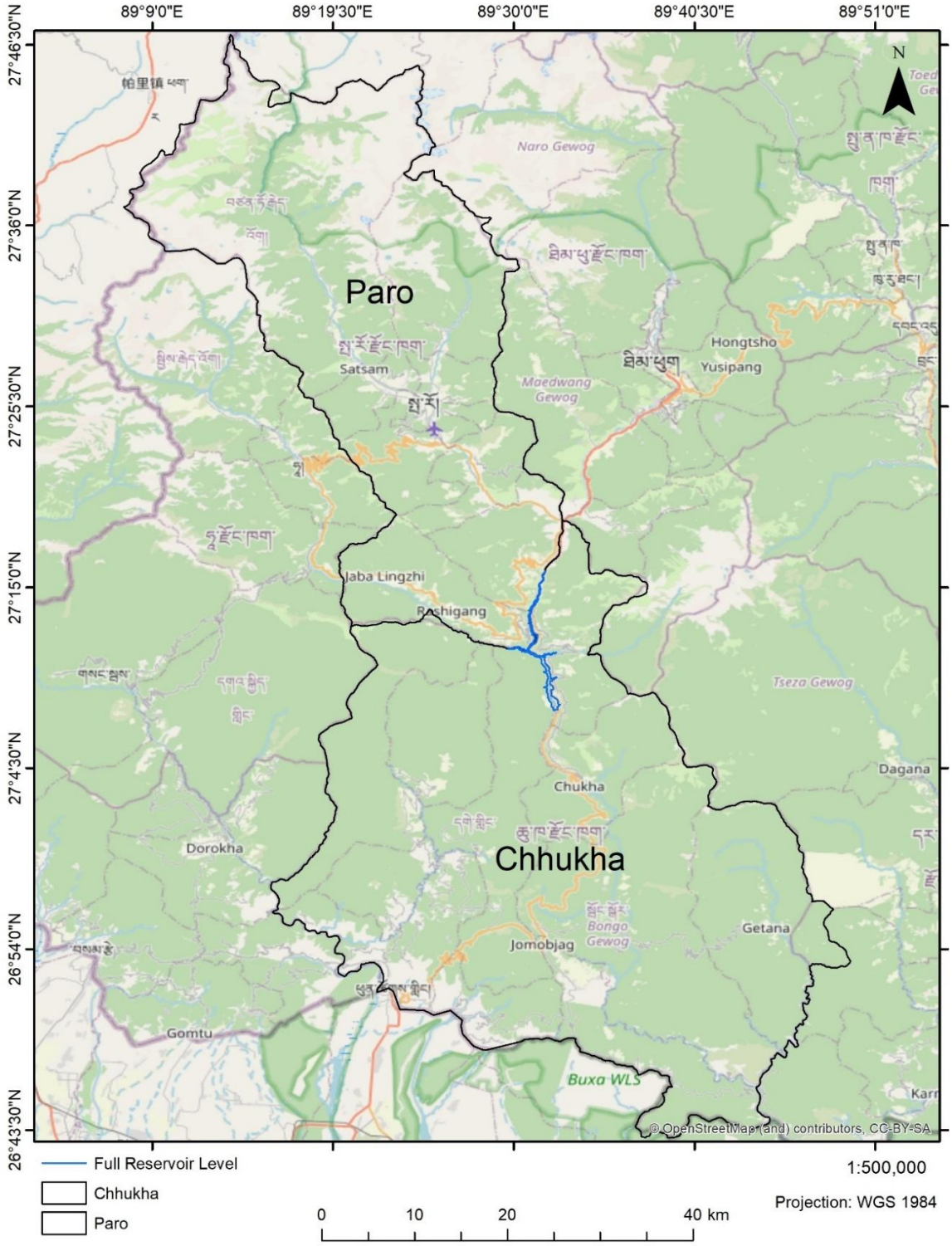


Figure 34: Location of the Bunakha HPP between the districts of Paro and Chhukha

Chhukha Dzongkhag comprises 1 Thromde/municipality, 1 Drungkhag/sub-division, and 11 Gewogs/blocks. The 11 Gewogs are: Bjagchhog, Chapchha, Bongo, Darla, Doongna, Getena, Geling, Logchina, Maedtabkha, Phuentsholing, and Samphelling (Figure 35).

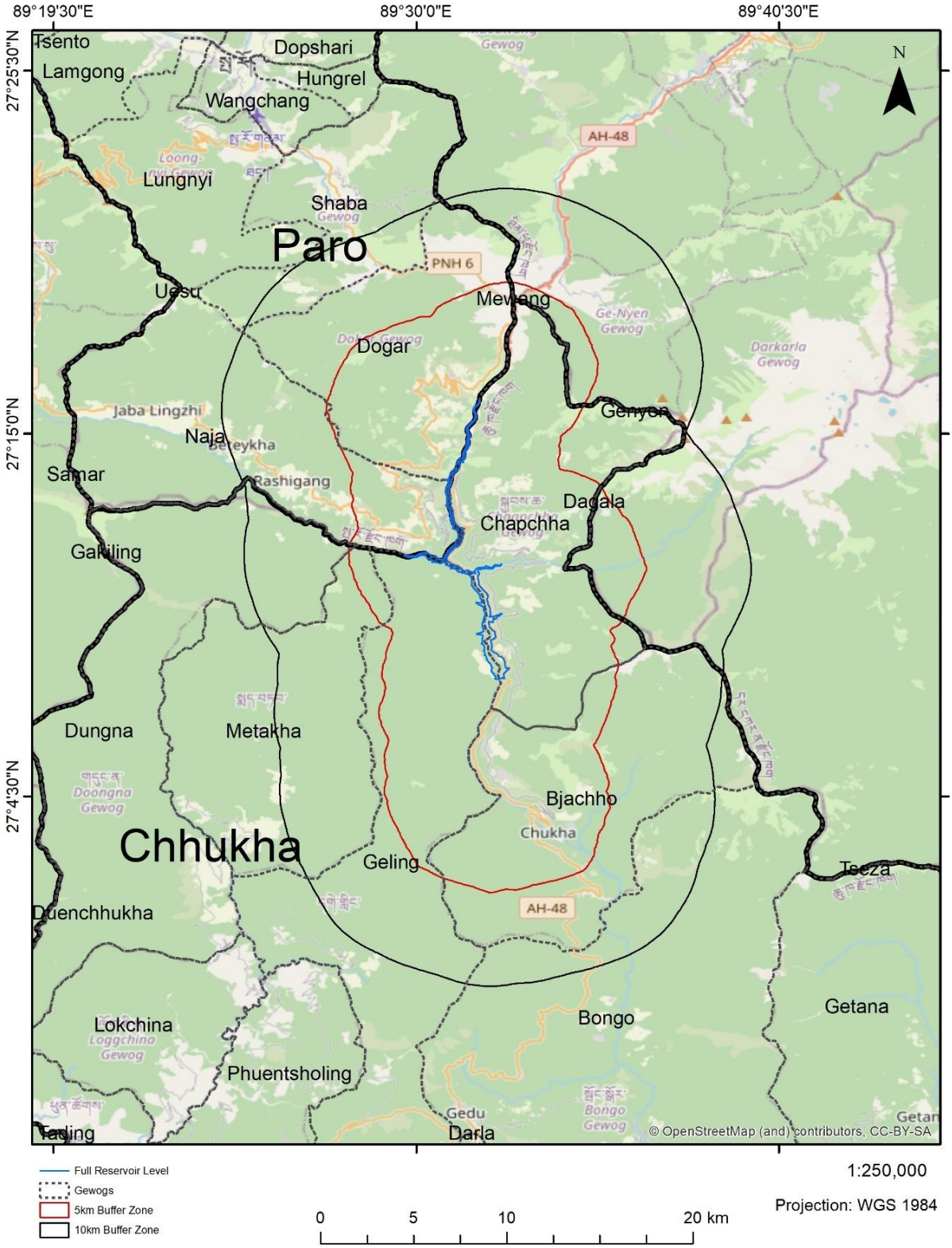


Figure 35: Gewogs within Paro and Chhukha Dzongkhags and relation to the Project's AoI

According to the Bhutan Living Standards Survey (BLSS), 2022, Paro Dzongkhag had a total population of 43,700 residing in 11,781 households, with an average household size of 3.7 persons. Female-headed households accounted for 35.0% of all households in the dzongkhag. Housing conditions indicate that metal sheet roofing is the predominant roofing material, used by 99.39% of households, followed by tin sheets (0.47%) and tiles (0.14%).

Access to basic services in Paro is generally high. All households (100%) have access to improved water sources, while 98.6% have access to improved sanitation facilities, comprising 100% of urban households and 98.15% of rural households. Approximately 40.0% of households use solid fuels for cooking, with a higher reliance in rural areas (47.0%) compared to urban areas (19.8%). Electricity access is nearly 100%, with 99.8% of households connected to the national grid and the remaining 0.2% relying on generators.

In Chhukha Dzongkhag, the total population was reported at 33,571 residing in 7,922 households, with an average household size of 4.2 persons. Female-headed households represented 26.7% of the total households. Similar to Paro, metal sheet roofing is the most common roofing material, accounting for 92.4% of households. Other roofing materials include tin sheets (5.99%), concrete/cement roofing (0.15%), tarpaulin (0.11%), planks/shingles (0.10%), thatch/banana leaves (0.09%), and other materials (0.06%).

Access to basic services is also high in Chhukha. Approximately 99.8% of households have access to improved water sources, including 99.7% of urban households and 100% of rural households. Improved sanitation coverage is universal at 100%. About 28.3% of households use solid fuels for cooking, with a significantly higher proportion in rural areas (61.6%) compared to urban areas (5.2%). Electricity access is almost universal, with 99.9% of households connected to the national electricity grid.

Overall, both Paro and Chhukha Dzongkhags demonstrate high levels of access to basic services, including water supply, sanitation, and electricity, reflecting the relatively strong socioeconomic conditions prevailing in the project area.

General literacy rate of Chhukha Dzongkhag is 71.4%, with a male literacy rate of 78.3% and a female literacy rate of 64.6%. In comparison, Paro Dzongkhag has a slightly higher overall literacy rate of 73.8%, comprising 81.7% literacy among males and 66.7% among females. This indicates that Paro exhibits marginally better educational attainment levels than Chhukha, while both dzongkhags show a noticeable gender gap in literacy, with male literacy consistently higher than female literacy.

According to the Bhutan Multidimensional Poverty Index (MPI), 2022, Paro Dzongkhag records one of the lowest levels of moderate poverty in the country at 8.1%, indicating relatively better overall socioeconomic conditions compared to most other dzongkhags.

In contrast, Chhukha Dzongkhag has a higher incidence of multidimensional poverty, with 8.4% of the population classified as multidimensionally poor. This suggests comparatively greater socioeconomic vulnerabilities in Chhukha than in Paro, although both dzongkhags remain below the highest poverty concentrations observed elsewhere in Bhutan.

The Chhukha Dzongkhag headquarters, which serves as the commercial hub for the region, is located about 12 km from the Project site. This area hosts essential amenities, including the Dzongkhag Administration, hospital, schools, police station, market, and other service facilities.

Chhukha Dzongkhag serves as the gateway to western and central Bhutan from India. Its administrative sub-division, the Drungkhag, is situated in Phuentsholing—one of Bhutan's busiest commercial centers. As a major town, Phuentsholing functions as the primary entry point for imports and the exit point for exports.

Established in April 1987, Chhukha Dzongkhag originally had a population of approximately 84,203. It spans an area of about 1,882.38 square kilometers, with elevations ranging from 160 to 4,480 meters above sea level. The Dzongkhag is well-connected to the capital city, Thimphu, via a double-lane highway. Farm roads now reach all Gewogs and Chiwogs, along with essential services such as drinking water, electricity, and mobile networks.

Table 36: Key social indicators of the Chhukha Dzongkhag

Indicators	Status (Chhukha Dzongkhag)	Status (Paro Dzongkhag)
Area (km^2)	1,882.38 km^2	1,293 km^2
Arable land	10.80% of the Dzongkhag area	
Municipalities (nearest municipality)	Tsimasham (Dzongkhag head quarter)	Punakha
No. of HHs	17,683	11,781
Population	68,966	43,700
Average HH size	3.9	3.7
General literacy rate	71.4	73.8

Source: Bhutan Living Standards Survey (BLSS), 2022 and Bhutan Multidimensional Poverty Index (MPI), 2022

Since 2016, all Gewog offices have been linked to GovNet through the Department of Information Technology and Telecom (DITT), Ministry of Information and Communications (MoIC). In the 2017–2018 fiscal year, the ICT office of Chhukha Dzongkhag extended this network to other government institutions, including Basic Health Units (BHUs) and schools.

The Dzongkhag is home to two major hydropower plants—Chhukha and Tala—which are vital contributors to Bhutan's national revenue. Pasakha, located within the Dzongkhag, is a prominent industrial township which is around 110 Km away from the Project site. Most residents rely on livestock and subsistence farming for their livelihoods. Paddy is the most widely cultivated food crop, while potatoes thrive at higher altitudes. At lower elevations, mandarins and cardamom are the primary cash crops.

On the right bank of the river lies Paro Dzongkhag, characterized by steep terrain with no human settlements or agricultural land owned or cultivated by local communities. The national highway, also designated as Asian Highway AH48, runs along the left bank of the Wangchhu River, just above the submergence level throughout the 17 km backflow stretch.

7.3.2 Project Gewogs

Gewog Administrations are headed by the Gup supported by the Gewog Administrative Officer, Mangmi, Gaydrung, Sector staff and Tshogpas.

7.3.2.1 Chuhukha Dzongkhag

Chapcha Gewog

Chapcha Gewog covers an area of 112.6 km² with a population of about 4,400 distributed across 386 households and 11 villages. The population is predominantly Ngalop, with livelihoods largely based on subsistence agriculture. The gewog also hosts several culturally and religiously

significant sites, including Bunakha Lhakhang, Dargay Choling Gonpa, Gangkha Lhakhang, and other local temples and monasteries, reflecting its strong spiritual and cultural heritage.

Geling Gewog

Geling Gewog has an area of 247 km² with a population of approximately 1,206 people in 135 households across 11 villages. The gewog is also predominantly Ngalop and Dzongkha-speaking, with key sacred sites such as Gangri Nye, Tshenge Nye, Bur Gonpa, and Kuenga Choeling Gonpa, indicating its cultural and religious importance despite its low population density.

7.3.2.2 Project Gewogs of Paro Dzongkhag

Dogar Gewog

Dogar Gewog in Paro Dzongkhag covers 106.1 km², with settlements distributed across multiple chiwogs. The gewog lies between 2,100 m and 4,700 m altitude, and land use is dominated by dryland agriculture, particularly wheat, barley, and cash crops. It has relatively small landholdings per household and shares boundaries with Haa, Thimphu, and Chukha Dzongkhags.

Naja Gewog

Naja Gewog covers 151.8 km² with around 3,002 people in 735 households across 22 villages. It has full electrification and mobile network coverage, and the population is supported by agriculture and livestock-based livelihoods. The terrain is gentle with elevations ranging from 2,290 m to 2,700 m, and the gewog has relatively well-developed basic services including schools, health facilities, and administrative infrastructure. [18]

7.3.3 Project Chiwogs

The Project site is situated between the Chiwogs of Bunakha and Chanachen, belonging to the Gewogs of Geling and Chapcha, respectively. The Chanachen Chiwog lies on the right bank of the Wangchhu River, while the Bunakha Chiwog is on the left bank (Figure 36). The dam location is approximately 3.25 km upstream from the existing Chhukha dam. Both Chiwogs are expected to experience some level of impact, with Bunakha likely to be more affected, particularly the paddy fields located below the national highway.

[18] *Source: Details regarding project Gewogs is accessed from paro.gov.bt , and chhukha.gov.bt*

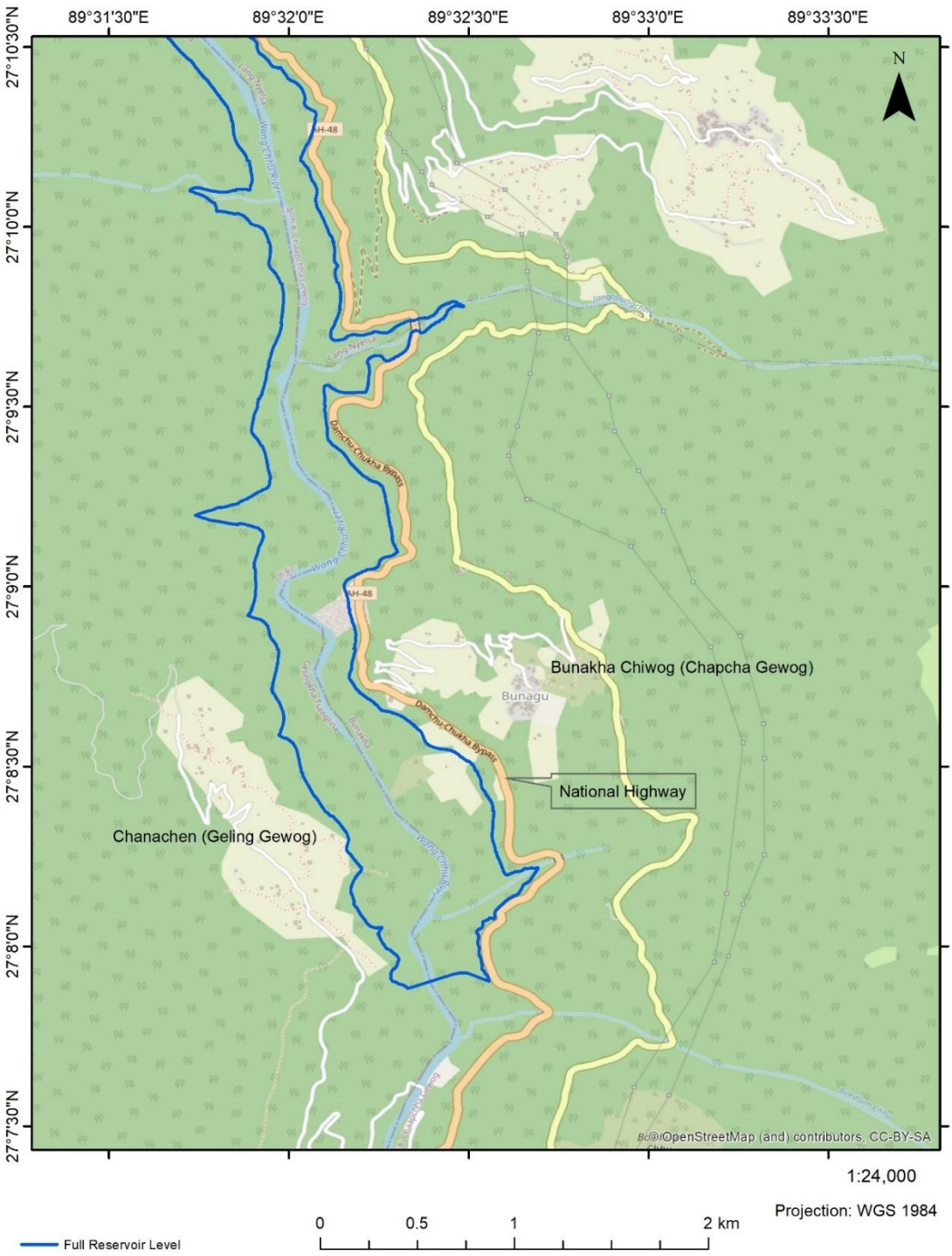


Figure 36: Bunakha and Chanachen Chiwogs located respectively at the left and right riverbanks; the reservoir (FRL) is marked with a dark blue line

The dam's backflow will extend about 17 km upstream, encompassing two additional Chiwogs—Tshamdrak and Shemanangkha—under Chapcha Gewog (Figure 37).

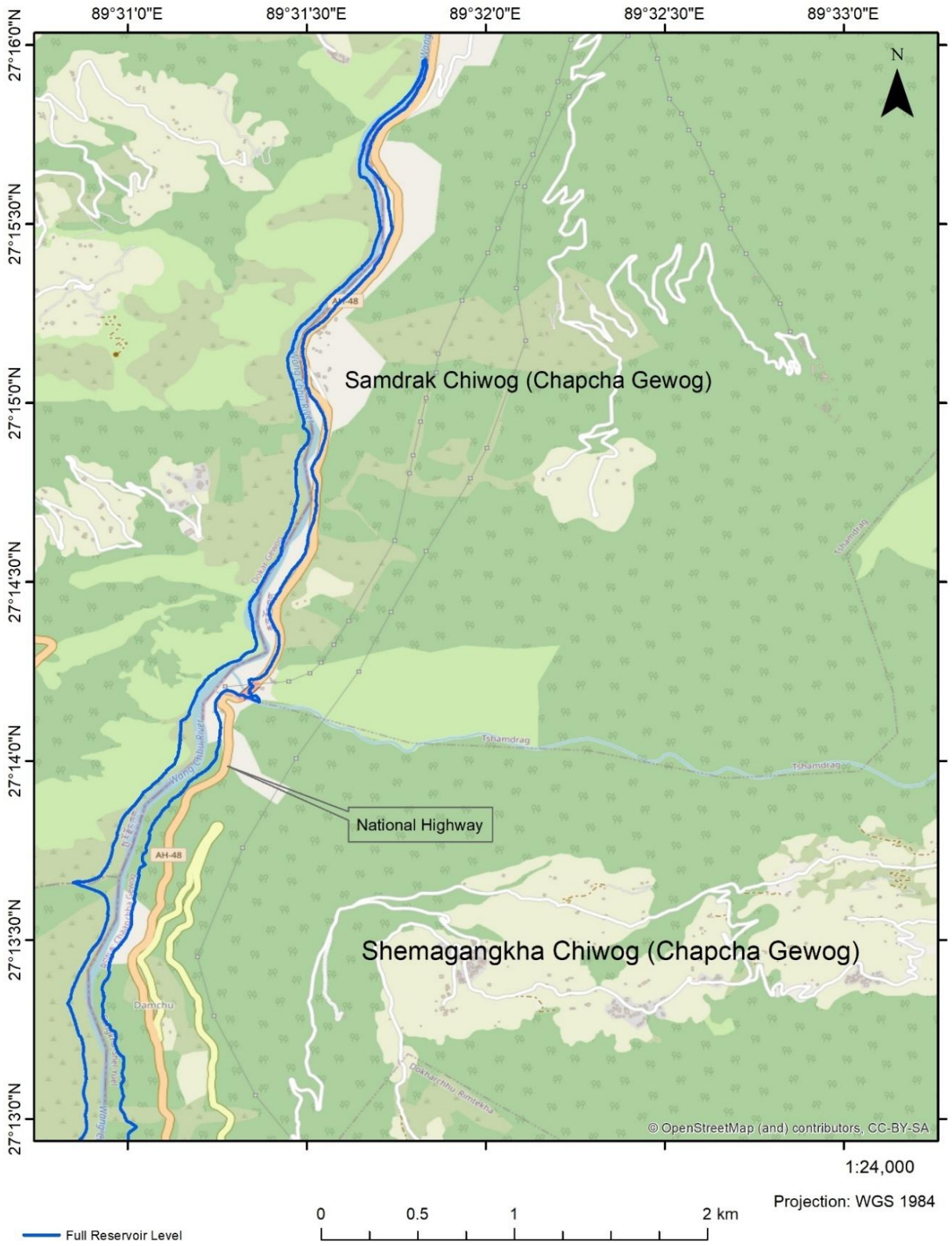


Figure 37: Shemagangkha and Tsamdrak Chiwogs (upstream of the Bunakha dam)

7.3.3.1 Key communities

The communities described below represent the principal human receptors within the Project Area of Influence. These settlements were identified through the area of influence assessment, socio-economic surveys, stakeholder consultations, and field observations. Their proximity to project components, dependence on local natural resources, and potential exposure to project-

related impacts make them particularly relevant to environmental and social impact assessment. Several permanent settlements are located within the AoI and are considered primary sensitive receptors due to their proximity to proposed construction activities and transport corridors. The location of these settlements is highlighted in **Error! Reference source not found.**.

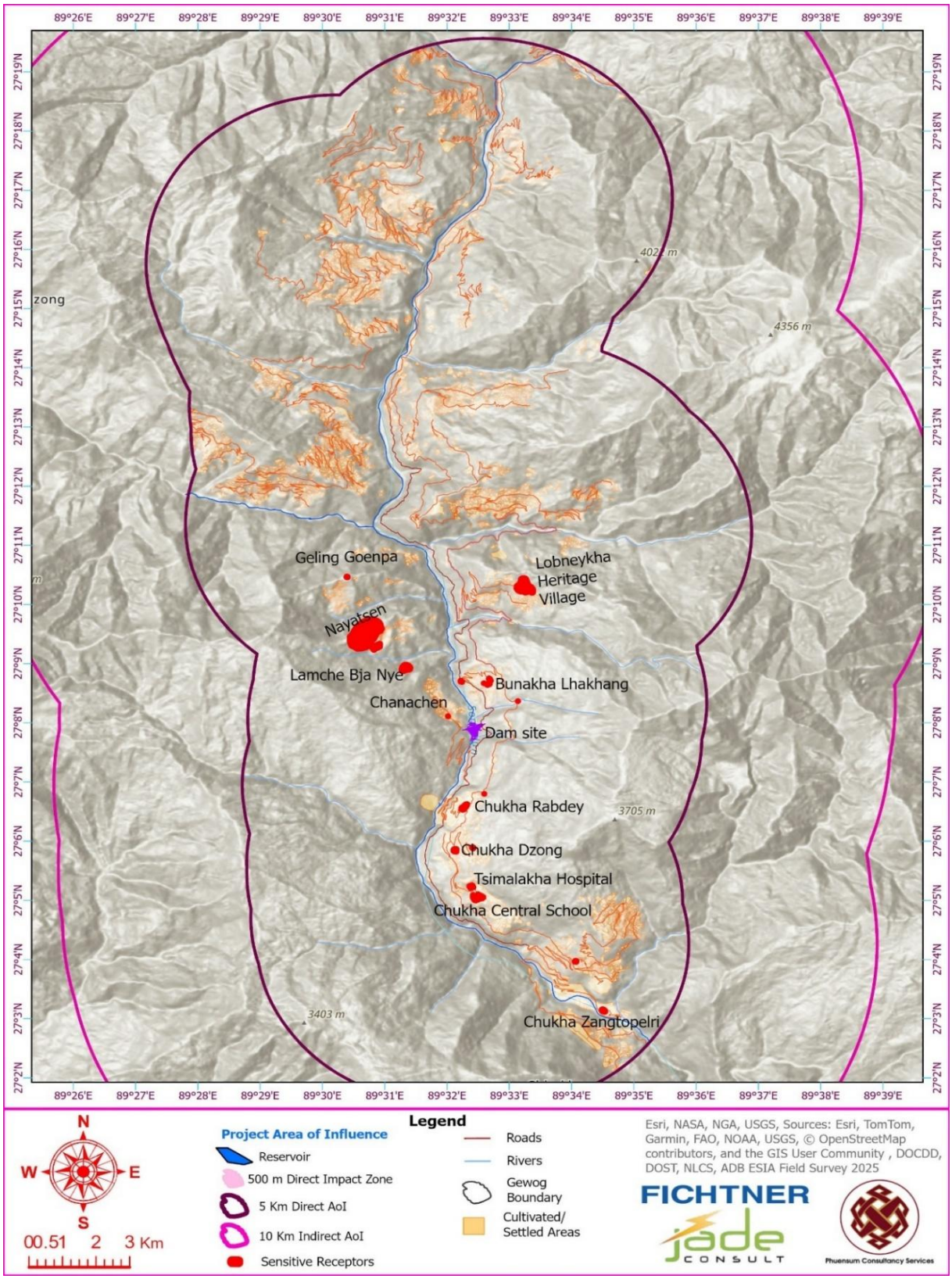


Figure 38: Key sensitive communities in the Bunakha HPP's AoI

Chanachen Village

Located on the right bank of the Wangchhu River, it is the most critically sensitive community within the Project's AoI due to its immediate proximity to high-impact facilities such as the main quarry, aggregate crushing units, and RCC/CVC batching plants. This positioning exposes residents to persistent noise, dust, vibration, and heavy traffic, creating a hotspot for cumulative environmental and social stress.

Baseline data from monitoring station ANSP-10 indicate an exceptionally quiet acoustic environment, meaning even moderate construction noise could cause significant disturbance and community dissatisfaction. Additionally, air quality monitoring reveals consistent exceedances of WHO guidelines for Nitrogen Dioxide (NO_2), pointing to a pre-stressed airshed with little tolerance for added emissions. The village's drinking water source (SW-10) is also vulnerable to contamination from nearby Project related activities. These factors collectively highlight Chanachen's sensitivity and reinforce the need for rigorous, source-level mitigation measures to be incorporated into the Environmental and Social Management Plan.

Nayakha Village

Situated further upstream, this village is identified as a sensitive receptor due to its extremely quiet acoustic environment and poor atmospheric dispersion characteristics. Baseline data from ANSP-9 revealed the lowest noise levels and the highest frequency of calm wind conditions (50%). This makes the community potentially vulnerable to noise intrusion (as they are accustomed to quiet conditions) and the local accumulation of air pollutants from construction traffic.

Bunakha Village

Bunakha Village, located on the eastern bank of the Wangchhu River, is a key residential and agricultural hub within the Project's AoI and home to the culturally significant temple Bunakha Lhakhang. The village lies directly along Asian Highway 48 (AH48), the main transport corridor for Project logistics, and near a proposed Project campsite (SSP-4), making it highly sensitive to traffic and construction-related impacts.

While shielded from direct construction at the dam and quarry sites, Bunakha faces risks from increased air pollution, noise, and vibration due to heavy vehicle movement. Baseline data shows existing exceedances of WHO guidelines for NO_2, O_3, and $PM_{2.5}$, a noise environment nearing disturbance thresholds, pristine soil vulnerable to contamination, and high-quality water sources at risk. These conditions make the village particularly sensitive to further environmental stress.

To mitigate impacts, the Project must implement targeted air, noise, and soil monitoring; develop community/public health and safety management measures to address traffic safety for AH48 through Bunakha; enforce strict controls on fuel and waste at ancillary facilities; protect water sources; and conduct structural and vibration assessments for Bunakha Lhakhang to preserve its integrity.

Tshimalakha Village

Tshimalakha is a key regional center that hosts critical facilities like the Tshimalakha Hospital and the Chhukha Central School. This makes the town a home to vulnerable populations such as children, the elderly, and patients who are especially sensitive to air and noise pollution. Additionally, and although the main Project traffic will bypass the town via Asian Highway 48,

internal vehicle movements—particularly those linked to the proposed Bunakha HPP colony—are expected to impact the local road network.

Baseline data from monitoring station ANSP-2 shows elevated night-time noise levels (53.09 dBA) nearing Bhutan's national limit, along with NO_2 concentrations exceeding WHO guidelines, indicating a stressed environment with limited tolerance for additional disruption.

The Chhukha Central School is centrally located within the Tshimalakha settlement between the hospital and the proposed Bunakha HPP Colony adjacent to environmental monitoring station ANSP-2 and water sampling point SW-5, making these data sources directly representative of its baseline conditions, which already show compromised air quality—particularly elevated NO_2 levels—and minimal acoustic headroom, with night-time noise nearing national limits. The school is a highly sensitive receptor due to its large population of children and its proximity to the main internal road used for project logistics. Although shielded from the main AH48 bypass, the school faces significant risks from local Project traffic.

The Tshimalakha Hospital, positioned on the northwestern edge of the settlement, is a vital healthcare facility and highly sensitive receptor, located approximately 1 to 1.2 kms from the proposed Bunakha HPP colony on the southeastern edge. Although the main project traffic will use the Damchu-Chhukha bypass via Asian Highway 48—avoiding direct passage through the settlement—the hospital remains exposed to localized project-related traffic accessing the colony, Tshimalakha Bazar, and other internal facilities.

Specific risks for the town, the school and the hospital include threats to pedestrian safety, especially for schoolchildren; interference with learning and recovery environments due to noise; and potential delays in emergency access to the hospital.

To address these concerns, traffic safety measures must be prepared for Tshimalakha's internal roads, developed in consultation with local authorities. Proposed are night-time noise controls, designation of low-speed school zones, preparation of a dedicated school zone protocol prohibiting heavy vehicle movement during student arrival and departure times, enforcing low speed limits, installing safety signage and crossings, and mandating driver safety training. Uninterrupted emergency access to the hospital must be guaranteed.

Direct consultation with the hospital and the school administrations and local authorities is essential to coordinate logistics and safeguard emergency access, while environmental monitoring at station ANSP-2 and SW-5 should be used to track changes in air quality, water quality and noise levels.

7.3.4 Land use/ land cover

Broadly, the land use pattern of the Project area is grouped into five categories (updated DPR, February 2026):

- agricultural / populated flatland: approx. 12% of the Project area
- thickly vegetated area: approx. 52% of the Project area
- moderately vegetated forest area: approx. 23% of the Project area
- open scrub area with lesser ground cover: approx. 9% of the Project area, and
- barren land: approx. 4% of the Project area

Within the submergence zone, private land comprises of approximately 31 acres of which approximately 36% remains fallow while the rest is being cultivated. This high percent of fallow uncultivated land reflects broader socio-economic shifts, including labour shortages, changing livelihood preferences, and increasing reliance on non-farm income sources. As a result, the potential agricultural loss due to submergence is relatively modest, but the transition underscores the need for livelihood diversification and support for households moving away from farming.

7.3.5 People

The Project Area of Influence (AoI) is predominantly inhabited by communities of Ngalong (Ngalop) ethnic origin, which constitute the largest and socially dominant ethnic group in Bhutan. Dzongkha, the national language of Bhutan, is the primary language spoken by affected households and communities, and residents actively participate in the national administrative, educational, economic, and political systems.

The affected communities share the same legal rights, governance structures, education system, cultural institutions, and public services as the broader Bhutanese population. Land ownership is formally registered through the national land administration system, and households possess legal land ownership certificates (Lag-thram) in accordance with Bhutanese law. Livelihoods are primarily based on agriculture, livestock rearing, small-scale business activities, wage employment, and government service, reflecting patterns commonly observed throughout rural Bhutan.

Based on the socio-economic surveys, consultations, focus group discussions, and review of secondary information, no distinct social group was identified that meets the characteristics of Indigenous Peoples as defined under ADB Safeguard Requirement 3. The affected population does not maintain separate customary political institutions, does not occupy geographically isolated territories, does not possess a distinct language separate from the national language, and is socially, culturally, economically, and politically integrated with mainstream Bhutanese society. Consequently, Indigenous Peoples safeguards are not triggered for the Project.

Notwithstanding the above, the ESIA recognizes the presence of potentially vulnerable individuals and households within the Project Area of Influence. These include elderly persons, women-headed households, persons with disabilities, economically disadvantaged households, and households that may experience disproportionate impacts from land acquisition or livelihood disruption. Specific measures to support vulnerable groups have been incorporated into the Resettlement Plan, Stakeholder Engagement Plan, Gender and Vulnerability Action Plan, and Grievance Redress Mechanism.

The Project Area of Influence is characterized by strong community cohesion, active participation in local governance structures, and close social and cultural ties to local religious institutions and cultural heritage resources. Community consultations undertaken during the ESIA process indicated broad recognition of the potential economic and infrastructure benefits associated with the Project, while also highlighting concerns related to land acquisition, livelihood impacts, downstream safety, cultural heritage preservation, and environmental protection. These concerns have been incorporated into the Project design and management measures described in this ESIA.

Table 37: Ethnic Composition of the Project Area

Indicator	Description
Dominant Ethnic Group	Ngalong

Primary Language	Dzongkha
Legal Status	Bhutanese citizens
Land Ownership	Registered through Lag-thram system
Governance	Integrated within national and local government structures
Indigenous Peoples Trigger (ADB SR-3)	No

The four Chiwogs located within the Bunakha HPP Project area - Tshamdrag, Shemagangkha, Bunakha, and Chanachen - are predominantly inhabited by communities of Ngalong ethnic origin, which represents the mainstream and majority ethnic group in Bhutan. Socio-economic surveys, stakeholder consultations, field observations, and literature review undertaken during the ESIA confirmed that the Project-affected households and communities within the direct impact area are socially, culturally, economically, and politically integrated with the mainstream Bhutanese population.

Residents of the Project area primarily practice subsistence agriculture complemented by livestock rearing and cultivation of potato and other cash crops as supplementary income sources. Men and women participate actively in agricultural and household livelihood activities. In contrast to some southern Gewogs of Chhukha Dzongkhag, property ownership within the Project area is predominantly held by women, with assets commonly inherited through matrilineal family systems.

From an ADB SPS (2009) perspective, the Project-affected communities do not exhibit the characteristics of distinct and vulnerable Indigenous Peoples groups as defined under Safeguard Requirement 3: Indigenous Peoples. The affected communities do not maintain distinct cultural, social, economic, or political institutions separate from the dominant society; they speak the national language, are not nomadic, and are integrated within the mainstream socio-economic and governance systems of Bhutan. Vulnerability identified during the socio-economic surveys is associated primarily with factors such as old age, disabillity, and household economic conditions rather than identification as a distinct social and cultural group.

Accordingly, based on socio-economic surveys, stakeholder consultations, field verification, and literature review, ADB Safeguard Requirement 3: Indigenous Peoples is not triggered for the BHPP.

Farming remains central to daily life in the Project area. Major crops cultivated include paddy, maize, potatoes, wheat, and seasonal vegetables. Livestock rearing is another important livelihood activity supporting household subsistence and supplementary income generation. Land represents the most valuable household asset and forms the basis of year-round livelihood activities. All households in the Project area possess permanent dwellings with access to electricity and drinking water supply. Motorable roads connect the Chiwogs to nearby markets and service centres, facilitating transportation of agricultural produce and access to public services.

Community assets within the Project area include Lhakhangs, religious structures, and designated community forests. The Bunakha Community Forest and Chanachen Community Forest are located above the old highway and Chanachen village respectively, while the community forests of Shemagangkha and Tshamdrag are situated above their respective settlements. These forests provide environmental, cultural, and livelihood benefits to local

communities and are considered important local resources within the broader Project area of influence.

Indigenous Peoples Screening

The applicability of ADB Safeguard Requirement 3 (Indigenous Peoples) was assessed during the ESIA and Resettlement Plan preparation process. The assessment was undertaken in accordance with the Indigenous Peoples characteristics described in the ADB Safeguard Policy Statement (2009), which considers whether a distinct social and cultural group possesses characteristics such as:

- Self-identification as members of a distinct indigenous cultural group and recognition of this identity by others;
- Collective attachment to geographically distinct habitats or ancestral territories and the natural resources within them;
- Customary cultural, economic, social, or political institutions that are separate from those of the dominant society and culture; and
- A distinct language, often different from the official or national language.

The communities residing within the Project Area of Influence are predominantly of Ngalong ethnic origin, which constitutes the majority ethnic group in Bhutan and forms an integral part of mainstream Bhutanese society. Residents primarily speak Dzongkha, the national language of Bhutan, participate in the national administrative and governance systems, and have access to the same public services, legal protections, educational opportunities, and economic systems as the broader Bhutanese population.

The affected households hold legally recognized land ownership rights under the national land administration system and are governed through the same administrative, legal, and local government structures applicable throughout Bhutan. No separate customary governance institutions, distinct political structures, or geographically isolated indigenous territories were identified within the Project Area of Influence.

Based on the available socio-economic information, stakeholder consultations, field observations, and review of secondary literature, the Project does not affect any distinct social group that meets the Indigenous Peoples characteristics defined under ADB SPS (2009). Accordingly, Indigenous Peoples safeguards are not triggered for the BHPP.

Table 38: Indigenous Peoples Screening Against ADB SPS Criteria

ADB SPS Indigenous Peoples Characteristic	Assessment for Project Area
Self-identification as a distinct indigenous cultural group	Not identified
Recognition by others as a distinct group	Not identified
Distinct customary institutions separate from mainstream society	Not identified
Distinct language separate from national language	Not identified
Collective attachment to separate ancestral territory outside national systems	Not identified
Social, cultural, economic and political integration with mainstream society	**Present**
Indigenous Peoples Safeguard Trigger	No

The affected households are predominantly of Ngalong ethnic origin, the majority ethnic group in Bhutan. They participate fully in mainstream Bhutanese social, economic, political, and administrative systems, speak the national language (Dzongkha), hold legally recognized land titles, and are governed under the same legal and administrative structures applicable throughout Bhutan. Based on the screening undertaken against the Indigenous Peoples' characteristics defined in ADB SPS (2009), no distinct social group meeting the SPS criteria for Indigenous Peoples was identified within the Project Area of Influence. Therefore, ADB Safeguard Requirement 3 is not triggered.

The RP survey undertaken for the Project indicate that the directly affected population consists of 30 affected households comprising 148 persons. Survey findings show that the affected households are predominantly of Ngalong ethnic origin, which represents the mainstream ethnic population of western Bhutan and the Project area. No distinct tribal, indigenous, or socially separate communities were identified among the affected households during the census, stakeholder consultations, focus group discussions, or key informant interviews. The affected households participate in the same socio-economic, cultural, administrative, and governance systems as the wider population of Chhukha and Paro Dzongkhags and do not maintain separate customary institutions, languages, territories, or livelihood systems that would distinguish them from the mainstream population as defined under ADB SPS (2009) Safeguard Requirement 3.

The RP survey identified a total of five persons with disabilities within the project-affected area. Among them, two individuals were reported with mental illness, one with mobility impairment, one with speech impairment, and one with partial hearing impairment. Three persons with disabilities were identified in Bunakha Chiwog and two in Chanachen Chiwog. The socio-economic survey identified five elderly persons aged above 80 years within the project area. Among them, three are female and two are male. Four elderly persons reside in Chapcha Chiwog, while one resides in Geling Chiwog.

7.3.6 Material and economic assets

In all four Chiwogs, households consider their homes and land as their most valuable assets. Every household has a permanent dwelling, with reliable access to electricity and clean drinking water. A motorable road runs through each Chiwog, making it easy to transport agricultural produce to external markets.

Land remains the cornerstone of their livelihood, supporting year-round agricultural activities essential for sustenance. Additionally, three households operate small businesses from their personal concrete buildings within the community. Common community assets comprise the community Lhakhangs and designated community forests. The community forests belonging to the four Chiwogs are situated within the Project's indirect AoI. Specifically, the Bunakha Community Forest lies above the old highway, while the Chanachen Community Forest is positioned above Chanachen Village. Likewise, the community forests of Shemagangkha and Tshamdrak are located above their respective Chiwogs.
The socio-economic survey indicates that households within the Project Area of Influence generally exhibit living standards consistent with rural communities in Chhukha and Paro Dzongkhags. Most households reside in permanent or semi-permanent structures constructed using reinforced concrete, stone masonry, timber, and corrugated galvanized iron roofing materials. Traditional Bhutanese architectural styles remain common, particularly in older residential structures.

Households generally possess a range of productive and non-productive assets, including agricultural land, livestock, farm equipment, household appliances, mobile phones, and motor vehicles. Agricultural land remains an important economic asset and source of livelihood for many households, supplemented by livestock rearing, wage employment, government service, small businesses, and remittance income.

Access to basic services is generally good. Most households have access to electricity, drinking water supply, educational facilities, healthcare services, mobile telecommunications, and road connectivity. The national electrification program and road network expansion have contributed significantly to improvements in living standards and accessibility within the Project Area of Influence.

While overall living conditions are relatively favourable, some households may be more vulnerable to project-related impacts due to limited landholdings, dependence on agriculture, age-related vulnerabilities, disability, or female-headed household status. These factors have been considered in the vulnerability assessment and in the design of mitigation and livelihood restoration measures described in the Resettlement Plan and associated management plans.

The Project Area of Influence is not characterized by extreme poverty or social exclusion; however, variations in household income, asset ownership, and livelihood dependence exist and have been considered during the impact assessment process to ensure that disproportionately affected households receive appropriate support and assistance.

Figure 39: Picture taken 21.01.2025 within project boundary of community structures.

Figure 40: Picture taken 22.01.2025 within project boundary of community structures.

7.3.7 Tourism

Currently, tourism within the Project area is virtually absent. Despite the presence of several nearby religious sites—such as Tshamdrak Goenpa, Bunakha Lhakhang, Shema Goenpa, Gangkha Lhakhang, and Geling Goenpa— approximately 17 kilometres from the Chanachen community, there is minimal external visitation. These sites are primarily frequented by local residents during auspicious occasions for religious offerings, with little to no influx of tourists or visitors from outside the community.

Currently, there is minimal tourist potential, resulting in a complete absence of tourist amenities in the communities.

The human environment within the Project Area of Influence comprises settlements, agricultural lands, community infrastructure, cultural and religious sites, and other locations that support the social, cultural, and economic well-being of local communities. Certain features within this human environment are particularly sensitive to potential Project-related impacts due to their social, cultural, religious, economic, or public service functions. Identification of these sensitive receptors is important for assessing potential risks associated with construction and operation activities, including noise, vibration, traffic, access restrictions, visual impacts, and community disturbance. The following section therefore identifies and describes the key sensitive receptors located within the Project Area of Influence that require particular consideration during impact assessment and mitigation planning.

7.3.8 Sensitive environmental receptors

The identification of sensitive environmental and social receptors is essential for understanding the potential pathways through which project activities may affect communities, livelihoods, public infrastructure, cultural heritage resources, and environmental values within the Project Area of Influence (AoI). Sensitive receptors include both environmental features and human populations that may be particularly vulnerable to project-related impacts during construction and operation.

Based on the baseline surveys, stakeholder consultations, and socio-economic assessments, sensitive receptors within the AoI include residential settlements, educational institutions,

healthcare facilities, religious and cultural heritage sites, agricultural lands, community infrastructure, environmentally sensitive habitats, and vulnerable population groups. The sensitivity of these receptors is influenced by their proximity to project activities, dependence on natural resources, social and economic conditions, and their importance to community wellbeing and cultural identity.

Particular consideration has been given to communities located in close proximity to the proposed dam, reservoir, access routes, construction facilities, and downstream river corridor, as these locations may experience direct or indirect impacts associated with land acquisition, construction activities, changes in river flow conditions, increased traffic, noise, dust, and public safety risks.

In addition to physical receptors, the assessment recognizes vulnerable population groups as socially sensitive receptors. These include elderly persons, women-headed households, persons with disabilities, economically disadvantaged households, and households experiencing significant land acquisition or livelihood impacts. The Project's mitigation measures, stakeholder engagement activities, and grievance mechanisms have been designed to ensure that the needs and concerns of these groups are appropriately considered throughout project implementation.

The following sections describe the key environmental and social receptors identified within the Project Area of Influence and their relevance to the environmental and social impact assessment.

The ESIA identifies receptors at specific locations, communities, or sites that are most vulnerable to potential adverse impacts from the Project, such as increased noise, dust, water and soil pollution, or social disruption. The following sections detail these receptors, providing the context for the targeted mitigation measures developed in the Environmental and Social Management Plan (ESMP).

The key sensitivities that must be addressed by the Project's design and management plans are:

- Acoustic and air quality sensitivity in Chanachen: Due to the co-location of multiple high-impact facilities (quarry, crushers, batching plants) near the village, Chanachen is the Project's primary hotspot for noise and dust impacts.
- Noise intrusion sensitivity in Nayakha and Tshimalakha: Nayakha is highly sensitive due to its pristine acoustic environment, while Tshimalakha is sensitive due to its proximity to the regulatory night-time noise limit. Stringent noise management protocols are required.
- Water source protection: The pristine quality of community springs (e.g., Chomteykha, Chanachen) makes them critically sensitive to any form of contamination. Their protection shall be an environmental management priority.
- Cultural heritage integrity: The proximity of construction activities and traffic to sites like Bunakha Lhakhang necessitates specific mitigation measures for noise, vibration, and dust to preserve their cultural and spiritual integrity.

7.3.8.1 Religious, historical and cultural heritage sites

The Project's AoI is embedded within a culturally significant landscape, encompassing over 30 religious and heritage sites. For assessment purposes, these sites are categorized by their proximity to construction zones and the level of potential impact. Those closest to major construction areas - such as the dam, quarry, batching plants, and transport corridors - are considered high-risk due to their exposure to noise, vibration, dust, and visual disruption. In

contrast, many sites located in the remote upstream sections of the AoI are shielded by distance and terrain, making them less vulnerable to direct impacts.

Figure 41 shows the location of the religious and cultural heritage sites within the Project's direct AoI.

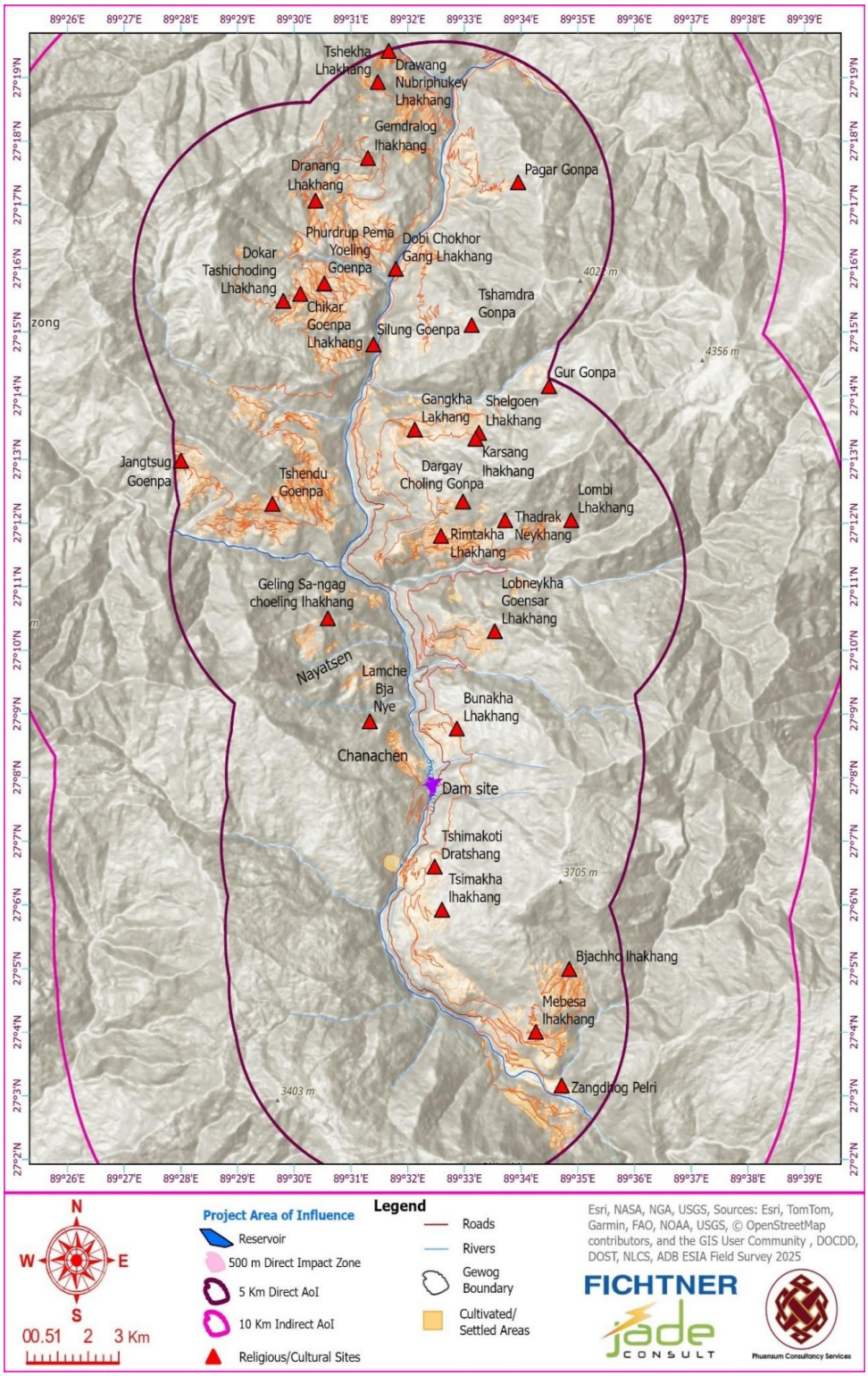


Figure 41: Key sensitive religious and cultural heritage sites in the Bunakha HPP's AoI

High-Risk Religious and Cultural Heritage Sites and Specific Sensitivities

The following locations are identified as particularly vulnerable and require focused protection and management:

- Bunakha Lhakhang: A prominent temple situated on the eastern riverbank, directly adjacent to the main access road. Its visibility from the proposed quarry and proximity to traffic routes make it highly susceptible to construction-related noise, vibration, and dust.
- Lamche Bja (Elephant Cliff): A spiritually revered cliff located upslope from the proposed quarry. During the public consultation held in Chanachen in July 2025, community members identified this as a critical issue. They expressed significant fear that blasting could disturb protective deities, raising a primary spiritual and cultural concern, while also voicing geotechnical concerns about the stability of the cliff face.
- Lobnekha Heritage Village: Positioned 3 -4 km north-northeast of the main activity zone, this settlement lies directly downwind. Prevailing wind patterns increase its exposure to airborne pollutants, including dust and combustion emissions.
- Nayatsen and Tsho Sacred Sites & Geling Goenpa: Located northwest of the Project site, these sacred sites and the active monastery share a downwind position. Baseline data indicates poor air dispersion and a quiet soundscape, making them highly sensitive to dust and low-frequency noise from blasting operations.

Religious and Cultural Heritage Sites with Low to Negligible Risk

Several other cultural sites within the AoI are considered low-risk due to their distance from construction activities. These are located several kilometers upstream of the Bunakha HPP dam axis and consist of a cluster of temples and monasteries -such as Tshekha Lhakhang, Drawang Nubriphukey Lhakhang, Pagar Gonpa, and Dobi Chokhor Gang Lhakhang.

Intangible Cultural Heritage

In addition to the tangible heritage sites identified above, the Project's AoI contains significant intangible cultural heritage (ICH) associated with the Ngalong communities of Bunakha and Chanachen Chiwogs. ICH in this context encompasses the living practices, knowledge, and spiritual traditions inseparable from the physical heritage sites described above, including:

Community rituals and ceremonies: Regular religious ceremonies, prayer sessions, and annual Tshechu (festival) observances are conducted at Bunakha Lhakhang, Geling Goenpa. These rituals constitute active living heritage directly associated with the physical structures within the Project's AoI.

Matrilineal inheritance traditions: The Ngalong matrilineal system of property inheritance from mother to daughter represents a living cultural practice of significant social and economic importance to the community, directly relevant to the Project's land acquisition and resettlement framework.

7.3.9 Results of the Socio-economic survey

The socio-economic survey conducted from 23 - 29 April 2025 covered 23 households comprising 61 individuals across Bunakha Chiwog (16 HHs) and Chanachen Chiwog (7 HHs) of Chapcha and Geling Gewogs respectively, representing approximately 31% of the combined residential population of the two Chiwogs.

The surveyed communities are predominantly of Ngalong ethnicity with deep historical ties to the area. The average household size is 2.6 members.

The resident population is consequently dominated by working-age adults (20–65 years), who constitute approximately 75% of permanent residents, alongside a notably high proportion of elderly persons aged 66 and above (nearly 25%), reflecting the out-migration of younger household members.

Agriculture is the foundation of local livelihoods, engaging 85% of surveyed individuals as their primary occupation.

The agricultural system is diversified, with rice, maize, wheat, potato, chilli, millet, buckwheat, radish, cauliflower, beans etcs., forming the principal crops, complemented by a range of seasonal vegetables grown for both household consumption and sale. Hazelnut cultivation represents an important but variable cash income source, with 11 of 23 households participating; kiwi, apple, Orchid, plum, peach and other fruit crops are also grown, though at levels insufficient to generate substantial income. Livestock rearing - primarily cattle - is widespread across both Chiwogs, with 18 of 23 households maintaining herds of varying sizes.

Food security is generally strong, with 91% of households meeting their food requirements from own production, the small number of food-insecure households supplement through business income or other sources mainly from remittances. Agricultural productivity is constrained by several pre-existing stressors - notably, 48% of households report insufficient irrigation water throughout the year, 100% experienced wildlife crop damage from wild boar, deer, bear etc., in the preceding 12 months.

Educational attainment is low, with 5% of surveyed individuals having no formal education, 65% of surveyed individual have no education, substantially limiting livelihood diversification capacity and access to formal employment. Approximately 70% of households depend on non-timber forest products - principally ferns and mushrooms - collected from nearby forests, as a supplementary livelihood resource.

Five persons with partial disabilities were identified across five households, spanning conditions of immobility, mental illness, speech impairment, and partial deafness.

Access to basic services is limited across both Chiwogs. There is no school within any of the villages, requiring children to travel to Chungkha, Kamji, or Tshimalakha at considerable distance. Health services are confined to periodic Outreach Clinics; serious medical needs require travel to District Hospital located at Tshimalakha. Access to Renewable Natural Resources services is uneven: Chanachen Chiwog benefits from local livestock, agriculture, and forestry services, while Bunakha residents must travel to the Dzongkhag headquarters or Gewog Centre to obtain similar support.

Women are the dominant social, economic, and institutional force across both Chiwogs, accounting for 60% of survey respondents, performing the majority of household responsibility, holding 70% of household property, serving as primary decision-makers in 52% of households - patterns firmly rooted in the matrilineal Ngalong inheritance tradition in which assets pass from mother to daughter.

The detailed results of the socio-economic survey can be consulted in **Error! Reference source not found. Error! Reference source not found.**.

8 Important Environmental and Social Components

The baseline assessment allowed the identification of the important environmental and social components (IESCs) for the Bunakha HPP, i.e., those elements of the biological, physical and human environment expected to be negatively or positively affected by the Project's implementation, and that require defining enhancement, avoidance, mitigation, and/or compensation measures.

A total of 17 IESCs are identified for the Bunakha HPP. These are described in Table 39.

Table 39: Important environmental and social components (IESCs) for the Bunakha HPP

IESCs for the Bunakha HPP	Site	Justification of the IESC
Physical Environment		
#1 Air Quality	Chanachen Village	Critical hotspot; downwind receptor during wet season; already experiences NO_2 exceedances above WHO guidelines
	Nayakha Village	Confirmed downwind sensitive receptor; poor air dispersion characteristics; prevailing up-valley winds transport pollutants from project activities; already experiences NO_2 exceedances year-round
	Bunakha Village	exposed to existing traffic emissions; near proposed construction activities; Bunakha Lhakhang cultural site at risk from dust
	Lobnekha Heritage Village	Positioned approx. 8-10 km north-northeast downwind; prevailing wind patterns increase exposure to airborne pollutants; heritage village with quiet soundscape
	Tshimalakha	Located approx. 5-10 km from project; hospital and Chhukha Central School present; already near night-time noise limit; exposed to AH48 traffic emissions
	Thimphu-Phuentsholing Asian Highway 48 _near by project area	Primary pollution source corridor; approx.1900 vehicles/day baseline traffic; heavy-duty trucks contribute >80% of NOx emissions; project traffic will add cumulative impacts
	Labtsakha	Campsite location; baseline monitoring station; represents background air quality conditions
	Dam area	Construction activity zone; air quality affected by dust from earthworks
	Proposed quarry site and muck disposal sites	area near Chanachen and bunakha; dust generation from extraction, crushing and disposal
#2 Noise Levels	Chanachen Village	Pristine acoustic environment (36-40 dBA baseline); surrounded by high-impact facilities
	Nayakha Village	Quietest area recorded (36.53 dBA night-time); pristine acoustic baseline; any construction noise will cause significant disturbance
	Bunakha Village (particularly Bunakha Lhakhang)	Cultural heritage site; adjacent to main access road; exposed to traffic and construction noise; vibration-sensitive structure
	Lobnekha Heritage Village	Heritage village; quiet soundscape; exposed to noise from blasting

IESCs for the Bunakha HPP	Site	Justification of the IESC
	Tshimalakha village	Night-time noise (53.09 dBA) nearing national limit of 55 dBA; hospital and school present-Tshimalakha Hospital and the Chhukha Central School
	Geling Goenpa	downwind position; quiet soundscape; sensitive to noise from blasting
	Nayatsen and Tsho Sacred Sites	Located northwest; downwind; poor air dispersion; quiet soundscape; sacred sites require acoustic protection
#3 Water Quality	Wangchhu River (upstream of dam)	pristine water quality; zero heavy metals; represents undisturbed conditions
	Wangchhu River downstream of dam	3.25 km upstream of Chhukha Dam; sensitive to turbidity from construction
	Nayakha Chhu	Nayakha village water source; added during wet season survey; community drinking water
	Chanachen Spring and community springs (Chomteykha, and Chanachen)	Chanachen village drinking water source; near quarry and batching plants; highest vulnerability to contamination
	Stretch from Bunakha Dam to Chhukha Dam	primary monitoring point for detecting project-induced water quality impacts
	Bunakha Reservoir (860.73 acres submergence)	free-flowing river to lentic system, pristine chemical quality (zero heavy metals)
#4 Soil Quality	main workshop area and vehicle maintenance yards (SSP-6)	Labour Camp-2 footprint; risk of hydrocarbon contamination from vehicles; near Chanachen
	RCC/CVC batching plants	Batching plant footprint (CVC/RCC); risk of soil alkalization from cement and concrete additive spills
	Agricultural soils - Bunakha and Chanachen Village	30.392 acres of privately owned land
	Topsoil layer (0-300mm)	High organic carbon (>0.95%); biologically active; critical for post-construction rehabilitation
#5 Land and Geology	Dam foundation area	Extensive excavation
	Reservoir area	860.73 acres submergence; converts terrestrial to aquatic habitat; permanent land use change
	INRQ-1 and INRQ-2 quarry sites	near Chanachen; aggregate source; blasting impacts on village
	Lamche Bja (Elephant Cliff)	Upslope from INRQ-3 quarry; spiritually revered; geotechnical stability concern; blasting vibration risk
	Diversion tunnel alignment	rock excavation; blasting required
	Slopes nearby Chanachen (near to river)	Steep terrain; landslide susceptible; below Lamche Bja; construction activity below
#6 River Morphology	Inundation area (17.25 km above the proposed dam location)	Altered flow regime will change riverbed elevation, bank stability, and sediment transport dynamics; requires e-flow maintenance

IESCs for the Bunakha HPP	Site	Justification of the IESC
	downstream section up to Chhukha Dam	
Biological Environment		
#7 Protected Areas, Critical Habitat & Ecological Connectivity	Project Area of Influence (AoI) including Bunakha village, Bunakha Chiwog, Chapcha Gewog, Wangchhu river corridor, reservoir footprint, upstream and downstream reaches, and surrounding forest divisions forming part of Bhutan's biological corridor network	▪ The project is located within Bhutan's conservation-oriented landscape under DoFPS, forming part of a legally designated biological corridor network. ▪ The AoI maintains landscape-level ecological connectivity linking forest habitats, wildlife movement routes, and riverine systems beyond the Project's physical footprint. ▪ IBAT screening, field surveys, and secondary data indicate presence and/or potential habitat of globally threatened species (CR/EN/VU), including White-bellied Heron, Red Panda, Dhole, and vultures. ▪ Based on the CHA, 6 species meet critical habitat criteria ▪ Project-related disturbances may contribute to habitat fragmentation, increased anthropogenic access, and disruption of ecological connectivity at the landscape scale.
#8 Terrestrial Habitats and Fauna	Reservoir inundation area (including drawdown zone), forested slopes, contiguous forest patches, ecological corridors, and access road alignments within the Project's AoI	▪ The AoI is dominated by subtropical broadleaf forests supporting diverse terrestrial biodiversity and key ecological processes. ▪ Forest habitats provide ridge-to-valley connectivity essential for species movement, gene flow, and habitat continuity. ▪ The area supports mammals such as Sambar, Himalayan Goral, Asiatic Black Bear, and potentially Red Panda and Dhole. ▪ Avifauna, including conservation-significant species such as White-bellied Heron and vultures, depend on forest canopy, riparian zones, and cliff habitats for feeding, nesting, and roosting. ▪ Herpetofauna occupy moisture-dependent microhabitats and are highly sensitive to microclimatic changes and habitat disturbance. ▪ Project-related disturbances including vegetation clearing, reservoir formation, and road construction may result in habitat loss, fragmentation, and disturbance to terrestrial fauna. ▪ Habitat fragmentation may reduce functional connectivity and affect long-term population viability of sensitive species.
#9 Aquatic Ecology and Environmental Flow Regime	Wangchhu River system within the Project AoI, including intake zone, reduced-flow stretch, tailrace discharge area, downstream reaches, and tributaries	▪ The Wangchhu River supports native fish species (e.g., *Schizothorax richardsonii*), but fish abundance is low between Bunakha and Chhukha dams. ▪ Aquatic habitats such as riffles, pools, and spawning grounds, are present but show limited functional use in the Project stretch. ▪ Longitudinal connectivity is essential for fish migration and lifecycle processes, however minimal

IESCs for the Bunakha HPP	Site	Justification of the IESC
		fish presence suggests limited migration activity in this reach. ▪ Aquatic ecosystems are highly sensitive to sedimentation, water quality degradation, and physical habitat alteration. ▪ Flow regime plays a important role in sustaining ecological processes; flow alterations may further constrain already limited biodiversity. ▪ The project will not fully dewater the river but will reduce flows in some stretches, which may affect aquatic habitats. ▪ Alteration of sediment transport dynamics and flow regulation may further influence channel morphology and aquatic habitat structure.
#10 Riparian and Interface Ecosystems	Riverbanks, tributary confluences, reservoir margins, and river–land interface zones within the Project AoI	▪ Riparian ecosystems provide essential ecological functions including bank stabilization, sediment regulation, and nutrient exchange; floodplain areas are absent in project AoI due to steep topography. ▪ These interface zones regulate microclimate and water temperature and support both aquatic and terrestrial species. ▪ Riparian habitats act as localized biodiversity hotspots for birds, amphibians, and invertebrates. ▪ Due to steep terrain, aquatic–terrestrial interactions are confined to narrow riparian corridors with limited lateral connectivity. ▪ Riparian ecosystems are highly sensitive to vegetation removal, sedimentation, water level fluctuations, and hydrological alterations associated with project activities. ▪ These ecosystems are functionally dependent on the hydrological regime and environmental flows, linking directly with aquatic ecosystem processes.
#11 Flora, Pollinators & Invasive Species	Forest areas within reservoir footprint, access roads, construction areas, muck disposal sites, camps, and disturbed zones within the Project AoI	▪ The AoI supports plant species of ecological, medicinal, and conservation importance, including species potentially protected under Bhutanese regulations or listed under IUCN categories. ▪ Vegetation clearing may result in loss of native flora, habitat degradation, and reduced regeneration potential. ▪ Disturbed areas such as roads, camps, and muck disposal sites are highly susceptible to colonization by invasive alien species, which may outcompete native species and alter ecosystem structure and function. ▪ Insects and pollinators (including butterflies) play a critical role in pollination, ecosystem functioning, and biodiversity maintenance and are sensitive to habitat disturbance and loss of floral resources. ▪ Spread of invasive species may increase due to construction activities and soil disturbance.
#12 Ecosystem Services	Entire Project Influence Area including forests,	▪ Ecosystem services are intrinsically linked to biodiversity and ecological integrity of the project area.

IESCs for the Bunakha HPP	Site	Justification of the IESC
	Wangchhu river system, riparian zones, and community-use areas within Bunakha Chiwog and Chapcha Gewog	▪ Provisioning services (e.g., freshwater, fuelwood, and NTFPs) exist; however, local communities have limited dependence due to their distance from the project AoI. ▪ Regulating services include erosion control, slope stabilization, sediment regulation, and maintenance of hydrological balance. ▪ Cultural services (e.g., landscape value, traditional practices, and spiritual significance) are present but are less directly utilized by nearby communities. ▪ Project-induced changes to habitat structure and ecological processes may affect the availability and sustainability of these ecosystem services, however, impacts on community reliance are expected to be limited.
Human Environment		
#13 Land and Assets	Geling and Chapcha Gewogs	44 affected households (218 persons) requiring land acquisition totalling 30.38 acres due to reservoir submergence; Including 1 hh needing residential house, impact on agriculture production and earnings
	Fruit-bearing trees	9 households affected, impact on livelihood and economic opportunities
	Physically displaced household	1 household (9 people i.e., 4F and 5M) requiring residential relocation; Bunakha Chiwog
	Severely Affected Households (SAHs)	35 HHs losing more than 10% of landholding **1 physically displaced HH mentioned above included SAH*
#14 Occupational Health and Safety	All construction sites	high-risk construction activities including 205 m high dam, extensive tunnelling, blasting operations, and 1,000 workers exposed to hazards such as working at heights, confined spaces, heavy machinery, and explosive materials.
#15 Community Health and Safety	Chanachen, Bunakha, Nayakha	Chanachen, Bunakha and Nayakha are located within 100 m to 1.6 km of high-impact activities including blasting, quarrying, and heavy traffic, with risks from vibration, dust, noise, landslides, dam failure,
	Downstream flood risk zone	Communities along Wangchhu River; includes Chanachen, Bunakha, and Nayakha potential dam failure or uncontrolled drawdown
	Landslide risk areas	Lamche Bja slopes; slopes above Chanachen; cut slopes along Chanachen farm road; tunnel portals
	Blasting exclusion zone	Areas near Chanachen and Bunakha
	Reservoir drawdown zone	Bank erosion risk; unstable slopes
#16 Infrastructures	Thimphu-Phuentsholing Asian Highway 48_nearby the Project area	Primary transport corridor; 1,935 vehicles/day baseline; heavy truck dominance; connects project to Thimphu and Phuentsholing
	Chanachen farm road	5.5 km access road to quarry and batching plants; narrow geometry; requires improvement; serves Chanachen village

IESCs for the Bunakha HPP	Site	Justification of the IESC
	Bailey Bridge over Wangchu River (27° 7'36.43"N, 89°32'21.73"E)	8 MT capacity over Wangchhu River; inadequate for project vehicles; requires replacement with 40R capacity bridge
	National Highway re-alignment	115 m section affected by dam excavation; to be shifted toward hillside
	Tshimalakha Hospital	Approximately 1 to 1.2 kms from the proposed Bunakha HPP; serves project area; vulnerable patients; emergency access critical
	Chhukha Central School	Large student population; near project logistics routes; children vulnerable to traffic accidents
#17 Cultural, Religious and Historical sites	Bunakha Lhakhang	Directly adjacent to the main access road
	Lamche Bja (Elephant Cliff)	Blasting could disturb the inhabitants
	Lobnekha Heritage Village	Positioned 3 - 4 km north-northeast of the main activity zone
	Nayatsen and Tsho Sacred Sites & Geling Goenpa	Downwind position, highly sensitive to dust and low-frequency noise from blasting operations.

In accordance with the ADB Safeguard Policy Statement (2009), Severely Affected Households (SAHs) include households that experience physical displacement and/or lose 10% or more of their productive assets or income-generating resources as a result of the Project.

Based on the detailed census survey, inventory of losses, and impact assessment undertaken during the preparation of the Resettlement Plan, twenty-three households have been identified as Severely Affected Households.

Of the 44 affected households (30 titleholder HH +14 collector HH) comprising 218 affected persons, one household will experience physical displacement through loss of its homestead and residential structure, while the second household will lose its landholding in totality, resulting in significant livelihood impacts.

Appropriate compensation, livelihood restoration assistance, transitional support, and additional measures for vulnerable and severely affected households have been incorporated into the Resettlement Plan in accordance with ADB SPS (2009) and relevant national legislation.

8.1 Sensitivity of the IESCs

This chapter classifies the degree of sensitivity of the IESCs to the expected Project impacts according to the methodology described in Chapter 5.3.1.

It is worth noting that the sensitivity of the IESCs is classified independently of the type and level of impact expected to be delivered.

Table 40: Classification of the sensitivity level of the physical environment IESCs

Sensitivity of the IESCs - Physical Environment

Criteria	#1 Air Quality		#2 Noise Levels		#3 Water Quality		#4 Soil Quality		#5 Land and Geology		#6 River Morphology	
	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring
Existing regulations and guidance	High	3	High	3	High	3	Medium	2	High	3	Very high protection level	4
Value of the receptor	High	3	High	3	Very High	3	High	3	Very High	4	Very High	4
Vulnerability to the changes	High	3	High	3	High	3	Medium	2	High	3	High	3
Reasoning	National limit for ambient air quality. Communities nearby very sensitive to air pollution. The vulnerability is high because even a small increase in emissions would push concentrations further above WHO guidelines		National limits for day time and night time. Communities nearby are sensitive to noise pollution that will created due to construction activities. The vulnerability is high because these receptors have extremely low baseline noise levels, and even a small external change would		National law has standards for river water quality (Class B) and drinking water quality. sources nearby support community health, drinking water supply, and aquatic ecosystems. The vulnerability is high because the pristine chemical baseline means any contamination would be immediately detectable, and the		National law has general qualitative requirements for land management. soil contamination would permanently affect land productivity and rehabilitation potential. with proper mitigation, the risk can be managed, and baseline soil is pristine with no pre-existing contamination.		National law provides high protection for land and geological features, requiring prior forestry clearance, quarrying leases, and environmental management plans for excavation activities. the reservoir area represents permanent loss of productive land.		National guideline provides high protection, requiring maintenance of environmental flows. The value is high because the Wangchhu River supports aquatic ecosystems, fish spawning grounds (Schizothorax richardsonii and Salmo trutta), and downstream infrastructure including Chhukha HPP (336 MW). The	

Sensitivity of the IESCs - Physical Environment

Criteria	#1 Air Quality		#2 Noise Levels		#3 Water Quality		#4 Soil Quality		#5 Land and Geology		#6 River Morphology	
	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring
			substantially disrupt the existing acoustic environment.		bacteriological contamination already present indicates vulnerability to further degradation.				even small external changes such as tunnel excavation, blasting vibrations could destabilize Lamche Bja, and excavation activities on steep slopes could trigger landslides affecting Chanachen village.		vulnerability is medium because with environmental flow maintenance (30% of lean season flows), downstream morphological monitoring, and bathymetric surveys every 5-10 years, the impacts can be managed and are reversible over long timescales.	
Sum	**9**		**9**		**9**		**7**		**10**		**11**	
Sensitivity of the receptor	**High**		**High**		**High**		**Medium**		**High**		**Very High**	

Table 41: Classification of the sensitivity level of the biological environment IESCs

Sensitivity of the IESCs - Biological Environment

Criteria	#7 Protected Areas, Critical Habitat & Ecological Connectivity		#8 Terrestrial Habitats and Fauna		#9 Aquatic Ecology and Environmental Flow Regime		#10 Riparian, Floodplain and Interface Ecosystems		#11 Flora, Pollinators & Invasive Species		#12 Ecosystem Services & Functional Ecology	
	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring
Existing regulations and guidance	Very High Protection Level	5	High	4	Very High Protection Level	5	High	4	Moderate	3	Moderate	3
Value of the receptor	Very High	5	High	4	Very High	5	High	4	High	4	High	4
Vulnerability to the changes	Very High	5	High	4	Very High	5	High	4	High	4	High	4
Reasoning	Located within a legally designated biological corridor under DoFPS, indicating very high regulatory protection. The receptor is of very high ecological value due to the presence/potential presence of globally threatened species and its role in maintaining landscape-level connectivity. Highly		Forest habitats with high ecological value supporting diverse fauna including conservation-significant species. Moderately to highly regulated under national forest and biodiversity frameworks. Vulnerable to vegetation clearing, habitat fragmentation, disturbance, and		River systems of very high ecological importance regulated under national water and environmental frameworks, with strong linkage to environmental flow requirements. Supports sensitive aquatic species and ecological processes dependent on flow regime. Highly vulnerable to flow		Ecologically important and partially regulated interface systems providing critical ecological functions. High value as transitional habitats supporting biodiversity and hydrological processes. Highly vulnerable to vegetation removal, hydrological alteration, sedimentation, and		Moderately regulated but ecologically important receptor supporting native vegetation and pollination processes. High ecological value due to role in ecosystem functioning and regeneration. Vulnerable to disturbance from clearing and construction		Moderately regulated but high-value receptor due to its contribution to provisioning, regulating, and cultural ecosystem services. Strong linkage with community dependence and ecological integrity. Vulnerable to cumulative changes in habitat structure, hydrology, and biodiversity	

Sensitivity of the IESCs - Biological Environment

Criteria	#7 Protected Areas, Critical Habitat & Ecological Connectivity		#8 Terrestrial Habitats and Fauna		#9 Aquatic Ecology and Environmental Flow Regime		#10 Riparian, Floodplain and Interface Ecosystems		#11 Flora, Pollinators & Invasive Species		#12 Ecosystem Services & Functional Ecology	
	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring
	vulnerable to project-induced fragmentation, increased access, and disturbance, which may disrupt wildlife movement and critical habitat functions.		edge effects resulting from reservoir inundation and infrastructure development.		alteration, sedimentation, and habitat modification associated with diversion and regulation.		reservoir-induced water level fluctuations.		activities, with increased risk of invasive species colonization in disturbed areas.		affecting service delivery.	
Sum	**15**		**12**		**15**		**12**		**11**		**11**	
Sensitivity of the receptor	**Very High**		**High**		**Very high**		**High**		**High**		**High**	

Table 42: Classification of the sensitivity level of the human environment IESCs

Sensitivity of the IESCs - Human Environment

	#13 Land & Assets		#14 Occupational H&S		#15 Community H&S		#16 Infrastructures		#17 Cultural, Religious and Historical Sites	
Criteria	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring	Classification	Scoring
Existing regulations and guidance	Very high protection level	4	Very high protection level	4	Very high protection level	4	High protection level	3	High protection level	3
Value of the receptor	Medium	3	Very high	4	Very high	4	High	3	Very high	4
Vulnerability to the changes	Medium	3	Medium	2	High	3	High	3	Medium	2
Reasoning	The IESC is protected by the Land Act, Resettlement Plan (RP) requirements, and ADB SPS. While most affected households can be compensated and supported toward livelihood restoration, the value and vulnerability of the receptor are classified as High because: (i) land is the primary productive asset for subsistence-farming households; (ii) 23 SAHs and (iii) 9 VAHs. Approximately 70% of households from socio-economic survey		The receptor "people", including workers, is highly protected by national and international regulations. The labour needs are very large for the construction and decommissioning, and medium for operation of the HPP, making the value of the receptor very high; vulnerability to changes can be classified as medium because workplaces are designed, regulated, and controlled environments, making them intrinsically less		The receptor "people" is highly protected by national and international regulations. The receptor includes specifically vulnerable sub-groups - female-headed households (70% of property ownership), elderly-headed households (persons 66+ age constituting approx. 25% of permanent residents), persons with disabilities (5 identified), and households with low education (66% no formal schooling) - who		Linear infrastructures are protected by national law and essential for local, regional and national connectivity, and therefore for economic development. Tsimilakha Hospital,Chhukha Central Schools play important roles in health care and education. Their value can be classified as high due to their national importance. They are considered highly vulnerable to changes brought up by the Project.		Several nationally protected (high protection level) and irreplaceable (very high value) monuments or archaeological sites are within the Project's AoI (Chapter 7.3.8)7.3.8.1). Bunakha Lhakhang, Lamche Bja,Lobnekha Heritage Village, Nayatsen and Tsho Sacred Sites and Geling Goenpa are particularly vulnerable. Several other cultural sites within the AoI are considered low-risk due to their distance from construction activities.	

	occasionally collect ferns, mushrooms, and other NTFPs from nearby State Reserved Forests primarily for household consumption rather than income generation. NTFP collection within the reservoir submergence area is limited, with most harvesting occurring outside the inundation zone; therefore, project impacts on access to these resources are expected to be minimal.	vulnerable to negative effects	face disproportionate health, and safety impacts. Considering this, the value of the receptor can be classified as very high, and the vulnerability to changes as high.		Beyond tangible structures, it encompasses ICH associated with these sites - including active community rituals, festivals, the spiritual significance of Lamche Bja as articulated by local Lams during consultations, and traditional ecological knowledge of Ngalong communities. The irreplaceable nature of ICH elevates the overall value of this receptor and is reflected in the Very High value score assigned. However, vulnerability to changes is expected to be medium with suggested mitigation measures (Cultural Heritage management plan).
Sum	**10**	**10**	**11**	**9**	**9**
Sensitivity of the receptor	**High**	**High**	**Very high**	**High**	**High**

9 Climate Impact Assessment

The term “climate change” is often used interchangeably with “global warming”. Global warming is caused by the so called “greenhouse effect”. This effect warms the lower atmosphere and Earth’s surface by a complex process involving sunlight, gases, and particles in the atmosphere. The greenhouse effect is a natural phenomenon caused by physical principles. However, recent human activity might increase this effect. The amounts of heat-trapping atmospheric gases, called “greenhouse gases”, have greatly increased since the mid-1800s, when modern industry became widespread. This is mainly due to an increased output of CO_2. There is no scientific doubt that this increase of CO_2 is one of the main reasons why the temperature of the earth's surface has risen significantly since the late 1800s.

9.1 Greenhouse Gas Emission Reductions Associated with Implementing the Project

The total national energy supply in Bhutan is estimated to be 793 kTOE or 9,200 GWh as of 2022 (Bhutan Energy Policy, 2025). Out of which, the thermal energy sources, which include coal and its derivatives, biomass, and petroleum products, constitute 62% of the total energy supply while the balance 38% is attributed to electricity. Bhutan’s electricity is 100% green and renewable, primarily generated from hydropower with an installed capacity of 3,490 MW as of June 2025, representing 11% of country’s techno-economic potential. The production from solar and wind sources is about 6 MW. Bhutan’s electricity grid is well connected to that of India leading to substantial amount of the electricity generation of Bhutan being exported to India. In 2025, about 73% of India’s electricity was generated by coal and fossil fuels. Hence, the baseline emission defined as the amount of emissions generated by grid-connected power plants when generating the same amount of power as the large hydro power plant is estimated using the grid emission factor defined for Bhutan and India in the ADB 2017 guideline [19], as estimated below.

The reservoir operation and simulation study (part of the 2026 DPR) estimates the annual energy generation from the Bunakha in terms of 6 hours/day of firm operating hours as presented in Table 43.

Table 43: Annual energy generation for Bunakha HPP for different exceedance probability

Item	Value
Average (GWh/a)	830.7
P50 (GWh/a)	822.9
P75 (GWh/a)	780.6
P90 (GWh/a)	746.5
LF (load factor)	0.47
Cu (utilization factor)	0.85
Peak Energy (%)	44%

Source: DPR, 2026

[19] Asian Development Bank (2017). Guidelines for Estimating Greenhouse Gas Emissions of ADB Projects: Additional Guidance for Clean Energy Projects (0 ed.). Asian Development Bank. https://doi.org/10.22617/TIM178659-2. This specific methodology applies to “power plant projects using large hydro resources with reservoir” (refer to Section III Specific Methodologies in ADB (2017) guideline).

Where:

$$Utilization\ Factor\ (\mathrm{Cu})\ [\%] = 1 - \frac{Avg.Volume\ Spilled\ [Mm3]}{Mean\ Annual\ Inflow\ [Mm3]}$$

$$Load\ Factor\ [\%] = \frac{Actual\ Energy\ Produced\ [\frac{MWh}{year}]}{Installed\ Power\ [MW] * hours\ per\ year\ [hs/year]}$$

The GHG emission reduction (ER) from the Bunakha Project is estimated using the following equation:

$$ER = BE - PE$$

$$BE = EG\ x\ EF_{grid}$$

$$PE = EG\ x\ EF_{hydro}$$

Where:

- BE = Baseline Emission - the amount of emissions generated by grid-connected power plants when generating the same amount of power as the large Bunakha HPP
- PE = Project Emission - the amount of emissions generated by the Bunakha dam / reservoir
- EG = Annual electricity generation by the Bunakha HPP, MWh/year
- EF_{grid} = Combined emission factor for the grid in Bhutan - estimated as 0.779 tCO_2/MWh[20]
- EF_{hydro} = Emission factor for larger hydropower to account for methane emission from dam - 0.090 tCO_2/MWh[21]

The Emission Factor (EF_{hydro}) considered in the ADB Guideline is based on the UNFCCC thresholds and criteria for the criteria for eligibility of hydroelectric power plants with reservoirs as CDM project activities (https://cdm.unfccc.int/EB/023/eb23_repan5.pdf). The UNFCCC criteria use the power density (W/m^2) threshold criteria. For projects with 4 to 10 W/m^2, an emission factor of 0.090 tCO_2/MWh is used to estimate project reservoir emissions. For projects with more than 10 W/m^2, the guideline recommends that the project emissions from the reservoir may be neglected. The Bunakha HEP has a reservoir area of 4.25 km^2, which gives a power density factor of 42.5 W/m^2 , a much higher power density than the 10 W/m^2 threshold, which would mean the reservoir emission could be neglected. For conservative estimates, we use the AB Guideline figure of 0.090 tCO_2/MWh for the emission calculation.

The construction emissions is estimated using the data from Life Cycle Analysis (LCA) of 178 hydropower cases carried out by Kadiyala, A., Kommalapati, R., & Huque, Z. (2016). The mean life cycle GHG emissions estimated though the LCA of 8 large hydropower projects with impoundments (reservoirs) is 40.64 gCO_2e/MWh. GHG emissions from construction activities (mining, steel, and concrete) are estimated to be from 30 – 70% of the total emissions. For the

[20] The source of the 0.779 tCO2/MWh grid emission factor for Bhutan is Appendix C Grid Emission Factors for Selected Countries of the ADB guideline. It should be noted here that the grid emission factor for Bhutan is considered in the same category as India by the ADB guideline, which is justified as Bhutan's electricity grid is well connected to that of India, leading to substantial amount of the electricity generation of Bhutan being exported to India.

[21] The methane emission estimate is considered after necessary measures are adopted to remove the trees and other vegetations from the reservoir area before filling.

Bunakha HEP with average annual generation of 831 GWh, the GHG emission estimate from construction activities would be in the range of 10,192 to 23,782 tCO_2e/MWh, which on an annual basis would be from 204 to 476 tCO_2e/MWh considering a project lifetime of 50 years. This is considered a negligible compared to the baseline emissions of the grid connected power plant of 180MW (831 GWh) capacity, and the conservative reservoir emission factor used for a project of high-power density threshold using by UFFCCC for CDM projects (project power density of 42.5 W/m^2 which is much higher than the UNFCCC threshold of 10 W/m^2)

Box 4: GHG emissions avoided from the Bunakha HPP

The GHG emissions reduction (ER) from the Bunakha HPP is **572,352 tCO_2** equivalent annually considering an 6-hours peaking operation.

Some additional energy generation, especially in the dry seasons, from the two downstream run-of-river projects (Chhukha and Tala) are also expected due to re-regulated flows from Bunakha HPP. This was not accounted for when determining the PE values.

9.2 Compatibility of the Project with Bhutan's Carbon Neutral Policy

The vision of the Climate Change Policy of the Kingdom of Bhutan (2020) is: "A prosperous, resilient and carbon neutral Bhutan where the pursuit of gross national happiness for the present and future generations is secure under a changing climate". Accordingly, the key policy objective of Bhutan is to "pursue carbon neutral development".

Hence, any replacement of the existing total thermal energy supply (currently 62% of the total national energy supply) by renewable hydropower energy sources contributes to Bhutan's carbon neutral policy. Bhutan's Energy Policy (2025) promotes expanding cross-border trade of clean electricity by engaging with evolving regional power markets, leveraging innovative mechanisms such as Renewable Purchase Obligations (RPOs), Renewable Energy Certificates (RECs), and other tools to contribute to regional GHG emission reductions.

The provisional Nationally Determined Commitment (NDC) 3 submitted by Bhutan on 10 November 2025 highlight the key role of hydropower and expansion of solar and other renewable energy sources in sustaining Bhutan's carbon-neutral commitment. The new NDC 3, which charts Bhutan's climate strategy up to 2035, reaffirms the historic 2009 promise to ensure that greenhouse gas emissions never exceed the carbon absorption capacity of the nation's forests (current coverage of 70.77% of the country) and land-based ecosystems. The policy integrates the enhancement of climate resilience and mitigation as a central objective in the country's future energy pathway.

According to Bhutan's Long-Term Low Greenhouse Gas Emission and Climate Resilient Development Strategy (LTS) (2023), the latest greenhouse gas (GHG) inventory compiled for the Third National Communication of Bhutan to the UNFCCC showed that in 2015, the gross emission was 3,814.09 $GgCO_2e$ and sequestration of 9386,59 $GgCO_2e$ resulting in a net sequestration of 5,572.50 $GgCO_2e$. The emission projections to 2050 show that carbon sequestration would reduce to 7,255 $GgCO_2e$ by 2050 due to pressures on forest land for development activities and forest disturbances in the form of outbreaks of pests and diseases and wildfires. With a business-as-usual (BAU) development approach, Bhutan's carbon neutrality pledge would be at risk by 2047 – 2048. Hence, Bhutan's LTS (2023) has developed a strategy with cumulative emission reduction targets in the key sectors (Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry, and Land Use (AFOLU) and Waste) up to 2050 at a cost of 220 million USD by 2050.

In view of the various climate and energy policies and strategies, the Bunakha HP Project's estimated emission reduction of 572,352 tCO_2 equivalent (or 572 Gg CO_2e), which is equivalent to 15% the estimate gross emission in 2015, is very much in line to contribute to meeting the Carbon Neutral Policy targets of the Government of the Kingdom of Bhutan.

9.3 Impacts of Climate Change on the Project – Climate and Disaster Risk Assessment (CDRA)

The key climate change-related impacts on the Project are expected to occur through the following pathways:

- Streamflows and energy generation
- Design flood- river floods, GLOFs, LDOFs
- Landslide and sediment load

9.3.1 Historical trend analysis

Analyzing trends in observed hydro-climatic variables provides initial insights into climate variability within the basin. Historical trend analysis at seasonal and annual scale was performed to detect the significance of variability in precipitation, temperature (minimum, maximum, and average), and river flow. A summary of the trends detected is shown in Box 5.

Box 5: Summary of historical climate trend analysis in the Bunakha HPP region

- Historical precipitation trend: mostly none
- Historical maximum temperature trend: varying / non-homogeneous within the basin
- Historical average temperature trend: mostly decreasing
- Historical minimum temperature trend: mostly decreasing

Eight climatological stations and four hydrometric stations are present in the Wangchhu basin upstream of Bunakha. Based on data availability, rainfall and temperature time series of six stations (Table 44) were selected for trend analysis using a Mann-Kendall test[22] to confirm the significance of the trend. For streamflow, timeseries at the Bunakha dam area (from the hydrology report prepared for the 2026 DPR) were taken for further analysis. In this analysis, daily time series were aggregated into seasonal categories: Winter (DJF), Pre-monsoon (MAM), Monsoon (JJAS), and Post-monsoon (ON).

Table 44: List of stations in the Wangchhu basin used for rainfall and temperature trend analysis

ID	Station	Subbasin	Latitude N (degree-decimal)	Longitude E (degree-decimal)	Elevation (m)	Data Available
12410046	Chapcha	Chhukha	27.1953	89.5308	2678	2000-2024
12510046	Bondey	Paro	27.3872	89.4195	2393	1997-2024
12580046	Nagtsho	Haa	27.4034	89.2617	2764	1996-2024
12650046	Babesa	Thimphu	27.4274	89.6458	2330	1996-2024
12810046	Drukgyel	Paro	27.4845	89.3303	2498	1996-2024
12900046	Begana	Thimphu	27.5700	89.6400	2492	2008-2024

9.3.1.1 Precipitation trend

Analysis shows that the **majority of the 30 analyzed time series exhibited a 'no trend' result**. However, six instances out of 30 cases {6 station (1 annual + 4 seasonal)} demonstrate a statistically significant trend (p-value < 0.05, 95% confidence) (Table 44). Of these, five were decreasing trends and one was an increasing trend. One more station is found to have a seasonal decreasing trend at 90% confidence (p-value <0.1). Across Wangchhu, the Sen's slope (rate of change, and in this case, precipitation change per annum) varied significantly, from a positive

[22] The Mann–Kendall trend test is a non-parametric statistical method used to detect whether a time series—such as rainfall, temperature, or streamflow—shows a monotonic (consistently increasing or decreasing) trend over time. The test evaluates the direction and significance of a trend by comparing all pairs of observations in the time series. A positive test statistic indicates an increasing trend, while a negative value indicates a decreasing trend. The associated p value determines whether the detected trend is statistically significant (Mann, H. B., 1945)

value of 7.518 mm/year at Chapcha during the monsoon season to a negative 6.955 mm/year for the Bondey annual data, indicating localized rainfall changes.

The significant decreasing trends in the annual rainfall for both Bondey and Drugyel stations is influenced by corresponding significant decreases during the monsoon (JJAS) period in Paro subbasin. In contrast, Chapcha station showed a statistically significant increasing trend during the monsoon (JJAS) season, with the highest rate (7.518 mm/year), even though its annual trend is not significant.

Table 45: Precipitation trend analysis at all stations in the vicinity of Wangchhu basin

Station	Scale	Trend	P-value*	Sen_Slope**	Significance
Chapcha	Annual	no trend	0.907	-0.214	Insignificant
	Winter [DJF]	no trend	0.069	-1.463	Insignificant
	Pre-monsoon [MAM]	no trend	0.234	-5.210	Insignificant
	Monsoon [JJAS]	**increasing**	**0.011**	**7.518**	**Significant**
	Post-monsoon [ON]	no trend	0.944	-0.042	Insignificant
Nagtsho	Annual	no trend	0.173	-2.641	Insignificant
	Winter [DJF]	**decreasing**	**0.045**	**-0.819**	**Significant**
	Pre-monsoon [MAM]	no trend	0.353	1.060	Insignificant
	Monsoon [JJAS]	no trend	0.149	-3.078	Insignificant
	Post-monsoon [ON]	no trend	0.921	-0.161	Insignificant
Bondey	**Annual**	**decreasing**	**0.046**	**-6.955**	**Significant**
	Winter [DJF]	no trend	0.387	-0.350	Insignificant
	Pre-monsoon [MAM]	no trend	0.418	-0.677	Insignificant
	Monsoon [JJAS]	**decreasing**	**0.046**	**-4.188**	**Significant**
	Post-monsoon [ON]	no trend	0.441	-0.549	Insignificant
Drugyel	**Annual**	**decreasing**	**0.007**	**-10.726**	**Significant**
	Winter [DJF]	no trend	0.588	0.000	Insignificant
	Pre-monsoon [MAM]	no trend	0.985	-0.056	Insignificant
	Monsoon [JJAS]	**decreasing**	**0.008**	**-9.375**	**Significant**
	Post-monsoon [ON]	no trend	0.388	-0.714	Insignificant
Babesa	Annual	no trend	0.666	-0.985	Insignificant
	Winter [DJF]	no trend	0.542	-0.170	Insignificant
	Pre-monsoon [MAM]	no trend	0.453	0.841	Insignificant
	Monsoon [JJAS]	no trend	0.464	-2.474	Insignificant
	Post-monsoon [ON]	no trend	0.793	-0.177	Insignificant

Station	Scale	Trend	P-value*	Sen_Slope**	Significance
Begana	Annual	no trend	0.303	-8.601	Insignificant
	Winter [DJF]	no trend	0.315	0.000	Insignificant
	Pre-monsoon [MAM]	no trend	0.343	4.321	Insignificant
	Monsoon [JJAS]	no trend	0.077	-14.503	Insignificant
	Post-monsoon [ON]	no trend	0.216	2.003	Insignificant

Notes:

* determines the statistical significance of the trend: typically, a p-value <0.05 (95% confidence) indicates a significant trend.

** rate of change, and in this case, precipitation change per annum

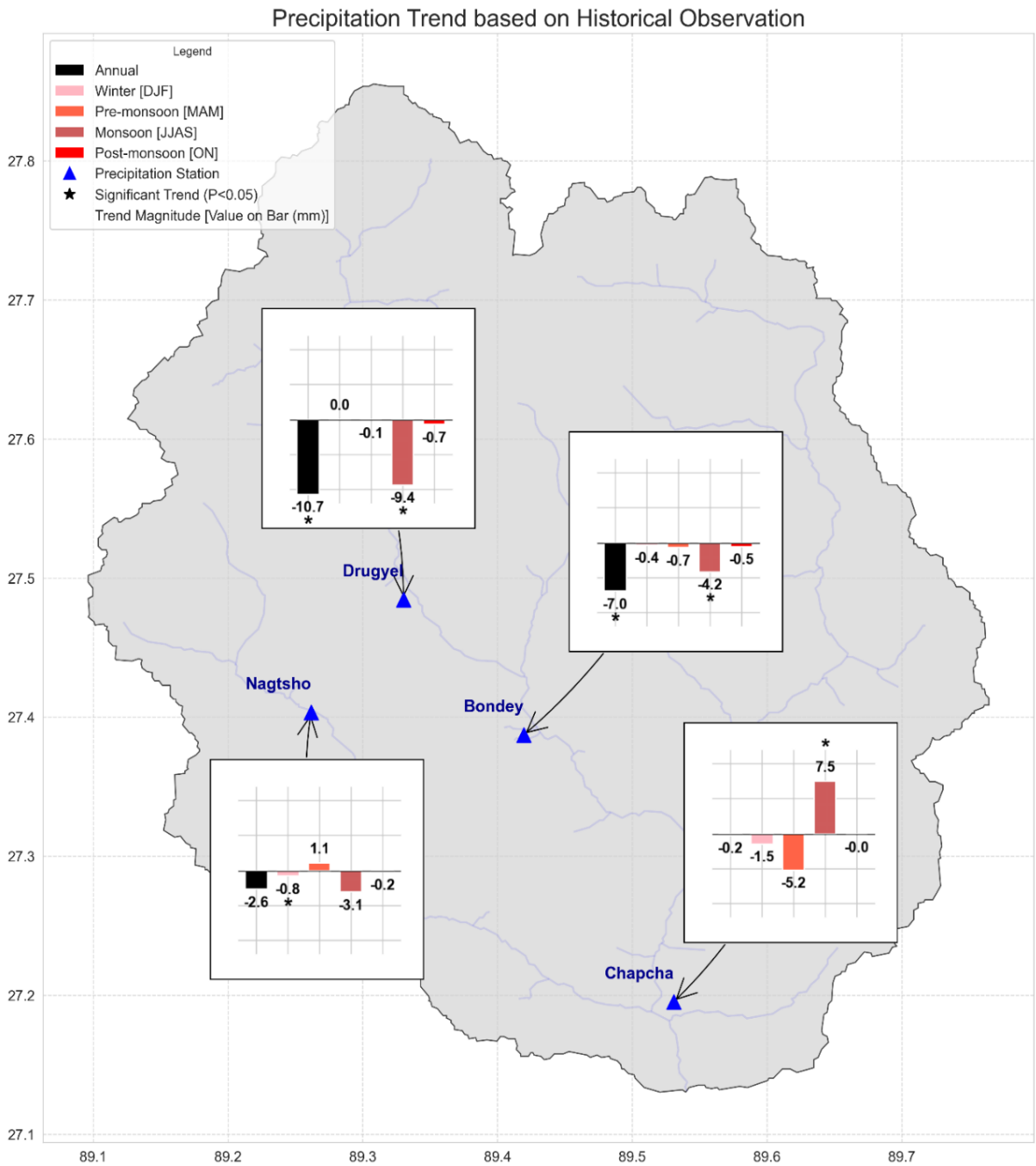


Figure 42: Map showing precipitation trend (mm/year) at stations (with significant trend) at seasonal and annual scale

9.3.1.2 Temperature trend

Maximum Temperature

Among six stations, only two stations (Begana and Chapcha) exhibited a statistically significant trend in maximum temperature (Figure 43). Begana showed a significant increasing trend in both annual and post-monsoon maximum temperatures, while Chapcha displayed a consistent and significant decreasing trend across all time scales. Sen's slope values for these significant trends range from -0.20 °C/year at Chapcha during winter to +0.165 °C/year at Begana during the post-monsoon period. These results indicate a clear difference in maximum temperature patterns, with one station in northern region experiencing a significant warming trend and another showing significant cooling trend. This **non-uniformity of change in maximum temperature trends** contrasts with the more widespread cooling observed in the average temperature data.

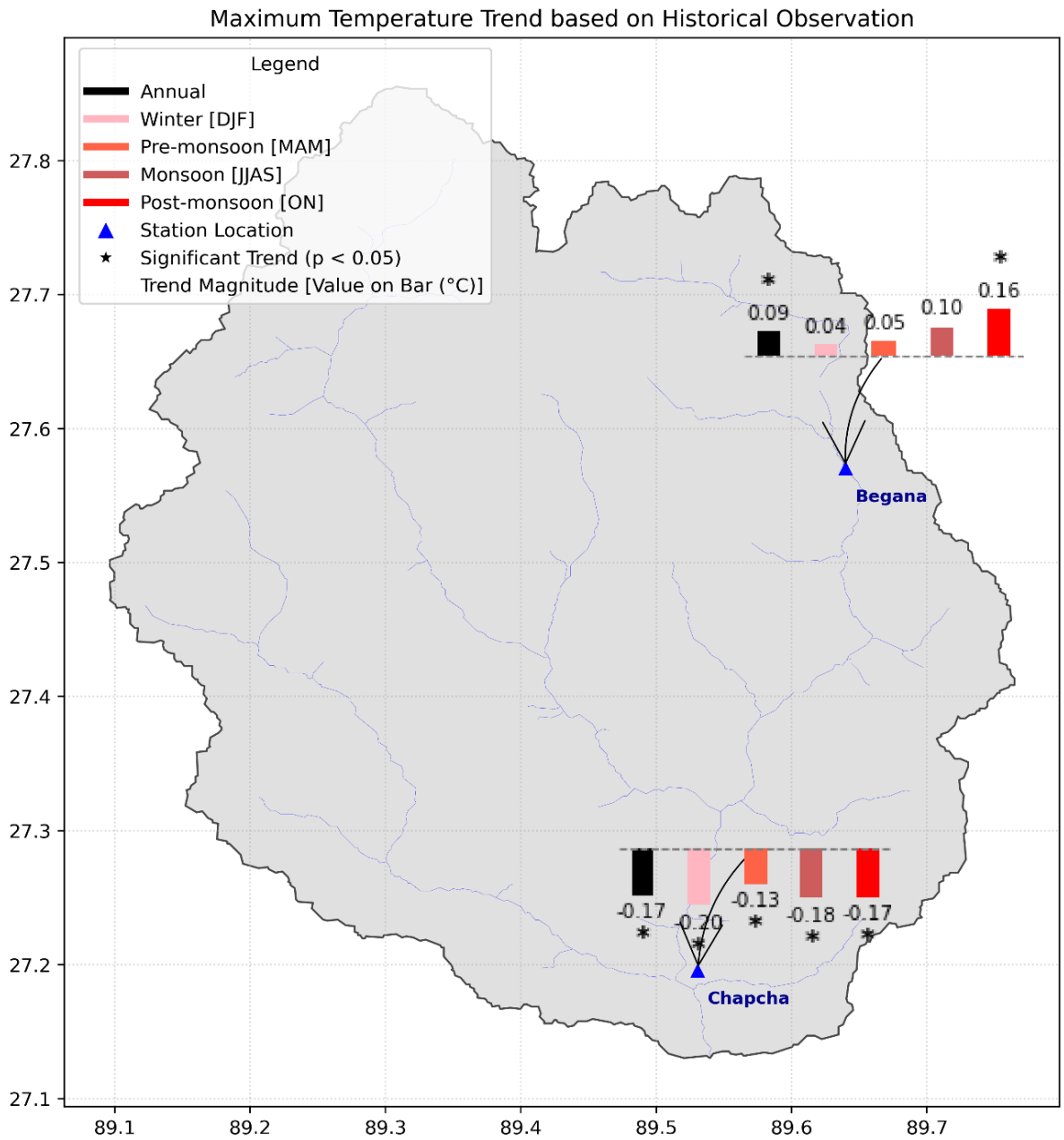


Figure 43: Map showing maximum temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale

Average Temperature

Babesa, Bondey, and Chapcha stations displayed significant **decreasing trends** at the annual scale (Figure 44) driven by consistent, significant decreases across all seasons (Table 46). A significant decrease with a Sen's slope of -0.22 °C/year, was observed at the Chapcha station during winter. In contrast, the only increasing trend found was a slight and statistically insignificant rise of +0.118 °C/year at the Begana station during the post-monsoon period.

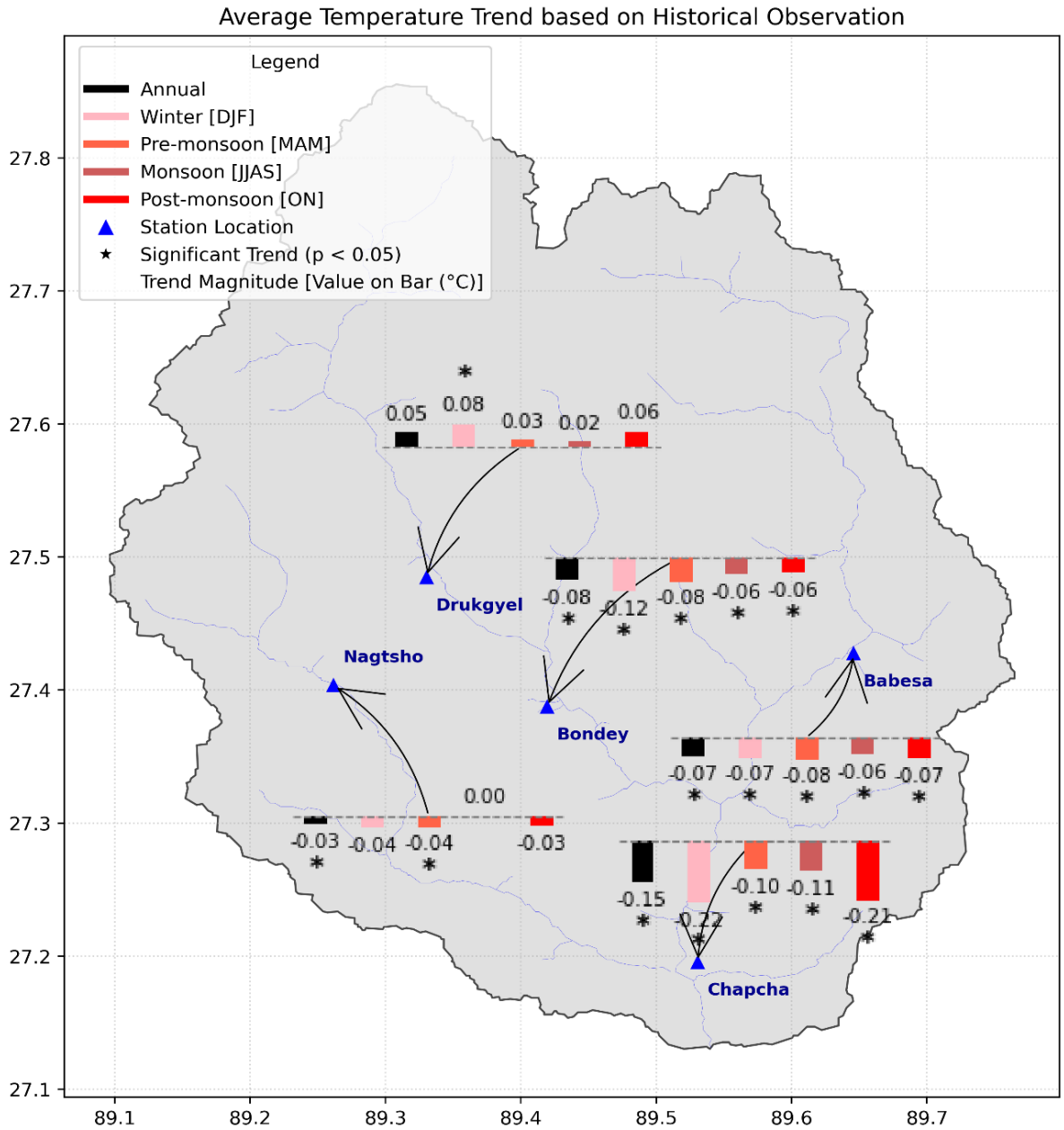


Figure 44: Map showing average temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale

Table 46: Average temperature trend analysis at all stations in the vicinity of Wangchhu basin

Station	Scale	Trend	P_Value	Sen's Slope (°C/year)	Significance
Babesa	Annual	decreasing	0.001	-0.069	Significant
	Winter	decreasing	0.004	-0.073	Significant
	Pre-monsoon	decreasing	0.003	-0.080	Significant
	Monsoon	decreasing	0.020	-0.061	Significant
	Post-monsoon	decreasing	0.005	-0.074	Significant
Begana	Annual	no trend	0.343	0.031	Insignificant
	Winter	no trend	0.805	0.017	Insignificant
	Pre-monsoon	no trend	0.837	0.022	Insignificant
	Monsoon	no trend	0.773	0.023	Insignificant
	Post-monsoon	no trend	0.202	0.118	Insignificant
Bondey	Annual	decreasing	0.000	-0.081	Significant
	Winter	decreasing	0.000	-0.121	Significant
	Pre-monsoon	decreasing	0.000	-0.085	Significant
	Monsoon	decreasing	0.001	-0.062	Significant
	Post-monsoon	decreasing	0.021	-0.056	Significant
Chapcha	Annual	decreasing	0.000	-0.150	Significant
	Winter	decreasing	0.000	-0.220	Significant
	Pre-monsoon	decreasing	0.042	-0.103	Significant
	Monsoon	decreasing	0.002	-0.109	Significant
	Post-monsoon	decreasing	0.001	-0.210	Significant
Drukgyel	Annual	no trend	0.053	0.053	Insignificant
	Winter	increasing	0.009	0.083	Significant
	Pre-monsoon	no trend	0.320	0.026	Insignificant
	Monsoon	no trend	0.084	0.020	Insignificant
	Post-monsoon	no trend	0.095	0.057	Insignificant
Nagtsho	Annual	decreasing	0.019	-0.028	Significant
	Winter	no trend	0.063	-0.040	Insignificant
	Pre-monsoon	decreasing	0.041	-0.038	Significant
	Monsoon	no trend	0.896	0.001	Insignificant
	Post-monsoon	no trend	0.072	-0.035	Insignificant

Note: A p-value < 0.05 (95% confidence) as used to define a significant trend, and there are additional 5 stations that had a p-value < 0.1 (90% confidence).

Minimum Temperature

Trend analysis revealed a **statistically significant cooling trend** across most stations (Figure 45). The most extreme rate of change was a significant decrease of -0.288 °C/year at the Chapcha station during the post-monsoon period. In contrast, the only significant increasing trend was a rise of 0.042 °C/year at Drukgyel (Paro subbasin) during winter. The most significant trends were observed at Babesa and Bondey, at all timescales showing a statistically significant decrease. This contrasts with the more mixed and often insignificant trends found in the maximum temperature data, suggesting that the primary driver of the overall cooling pattern across the region (observed in average temperature case - see previous paragraph) is a decline in minimum temperatures.

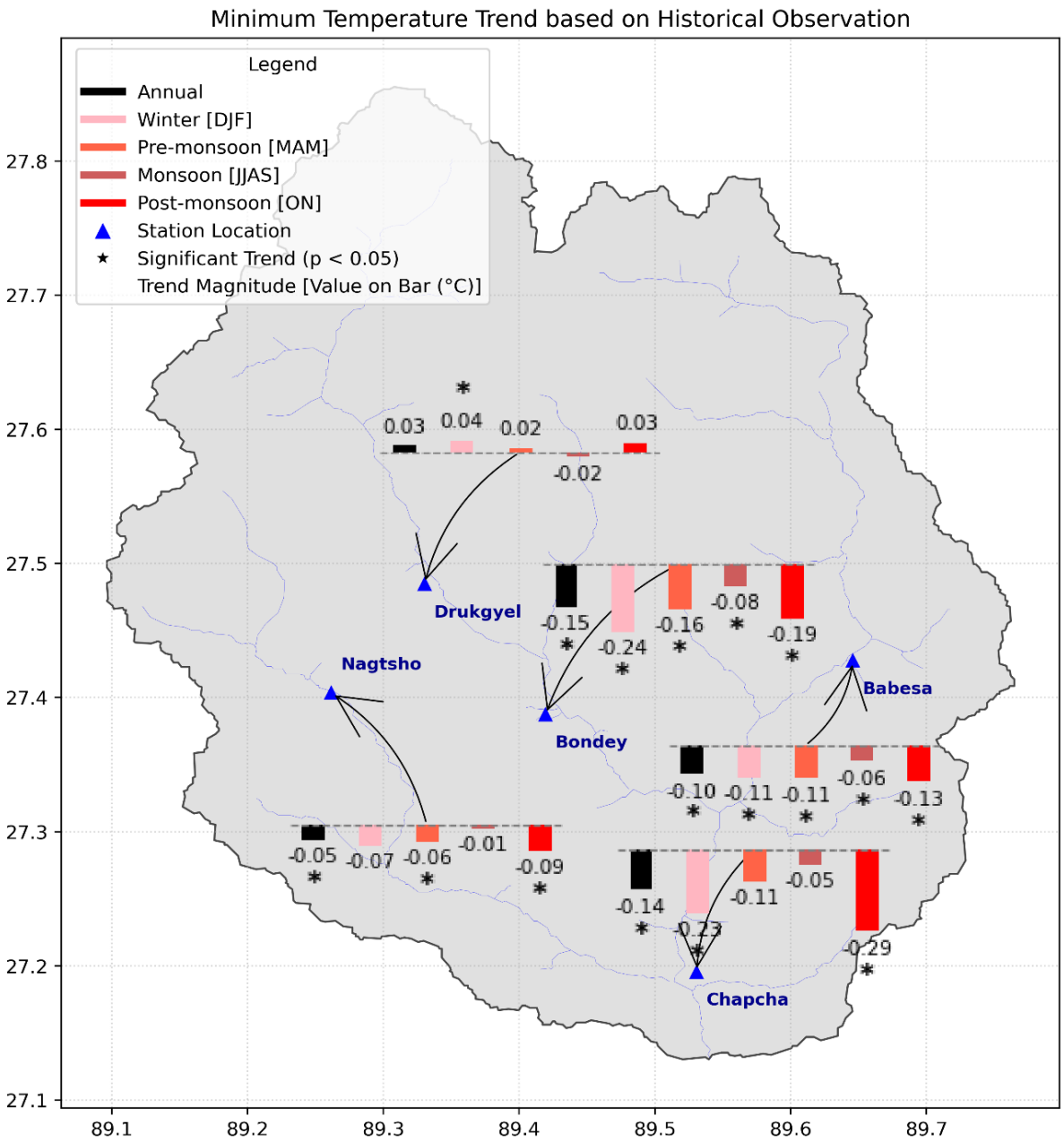


Figure 45: Map showing minimum temperature trend (°C/year) at stations (with significant trend) at seasonal and annual scale

9.3.1.3 Streamflow trend

Trend analysis of streamflow data at Bunakha dam reveals a clear and significant decreasing trend across all timescales (Figure 46 and Figure 47).

Annual, winter, and monsoon exhibited a statistically significant trend ($p < 0.05$), all of which were decreasing. The annual streamflow showed a highly significant decreasing trend with a Sen's slope of -0.426 m^3s per year. This significant decrease was also evident in the seasonal data, with both the winter and monsoon periods showing significant decreasing trends.

The most pronounced decrease was observed during the Monsoon season, with a rate of -0.987 m^3/s per year although this rate is relatively small in absolute terms. These reduction in water availability for the Bunakha dam aligns with observed trend in precipitation and temperature trends in the Wangchhu basin.

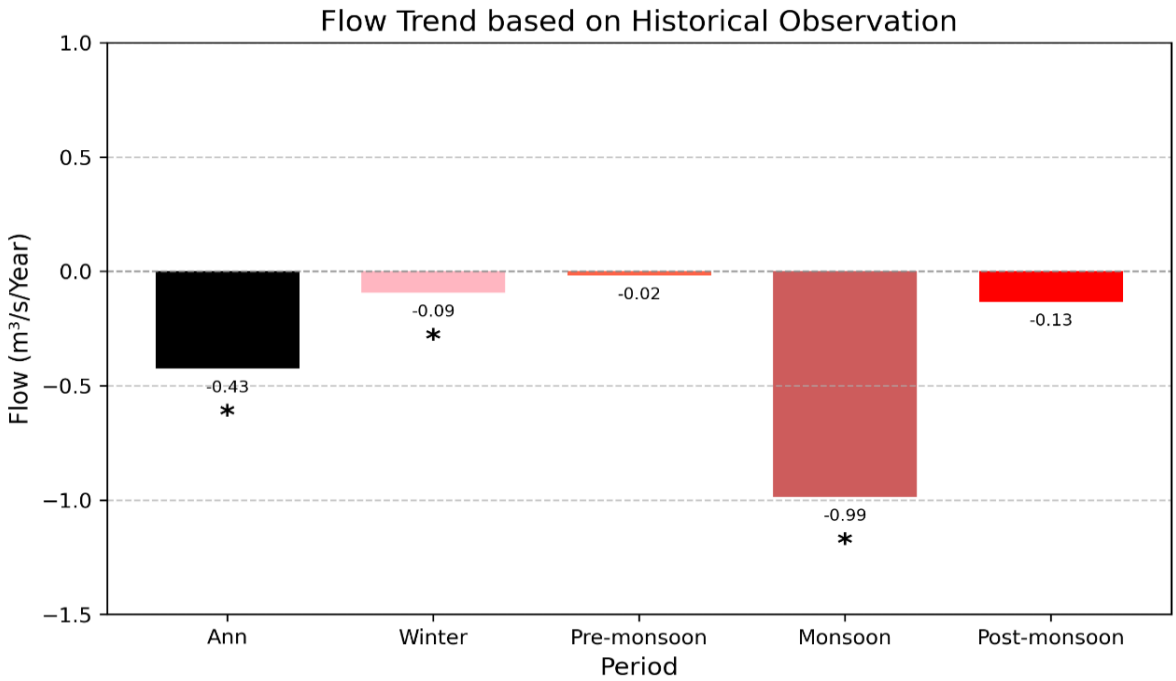


Figure 46: Flow trend ($m^3/s/year$) magnitude at Bunakha dam at seasonal and annual scale

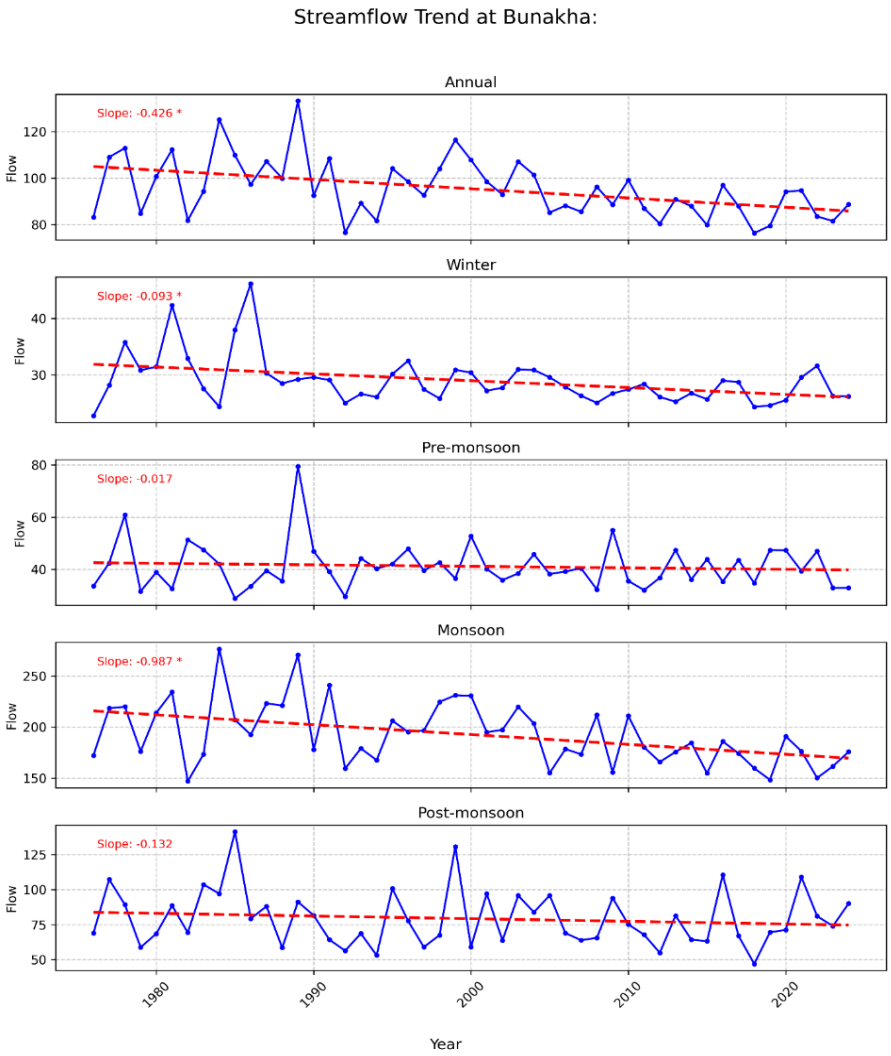


Figure 47: Seasonal and annual flow timeseries at Bunakha dam

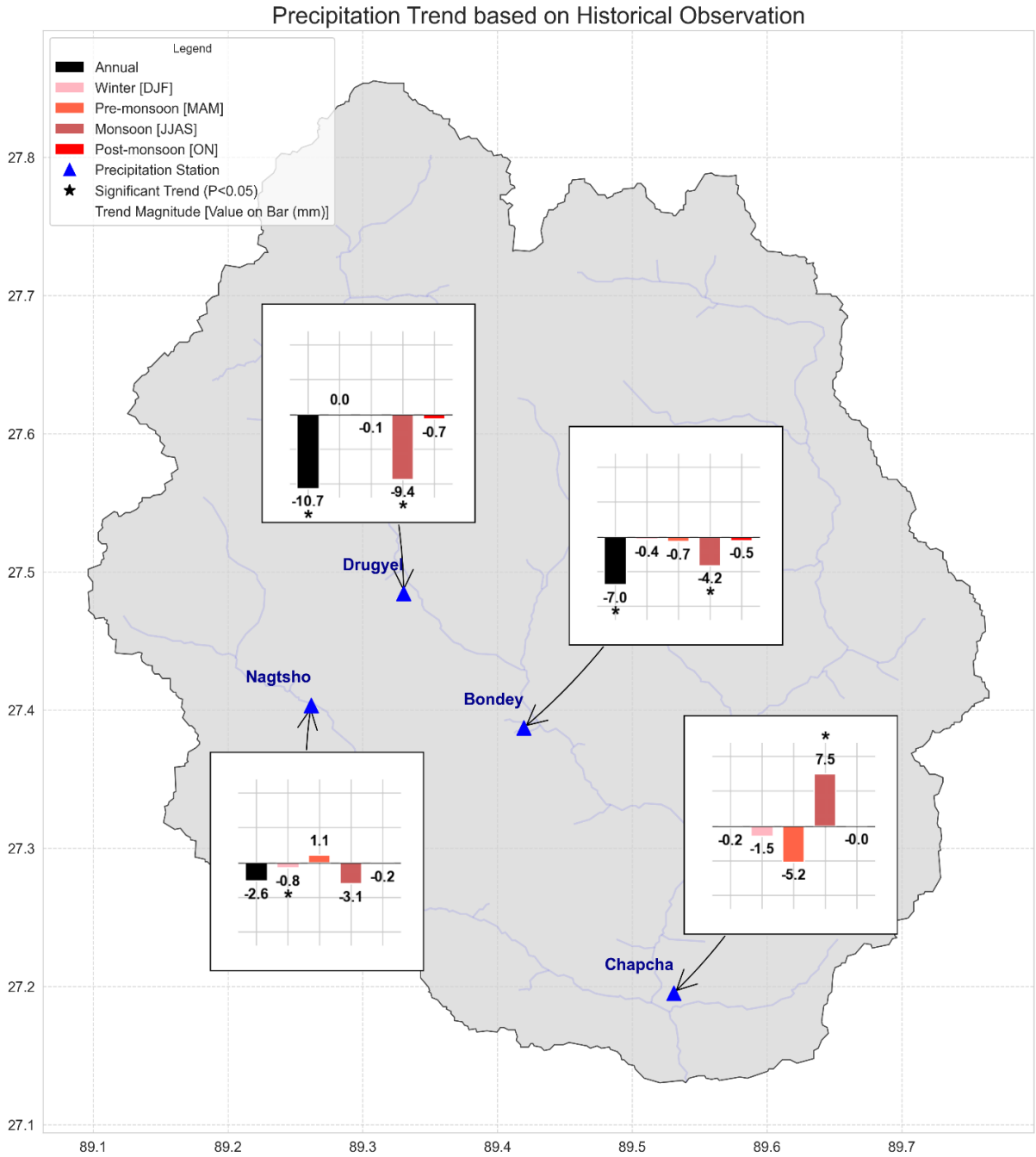


Figure 48: Map showing precipitation trend (mm/year) at stations (with significant trend) at seasonal and annual scale

9.3.2 Climate change projections

This analysis uses the precipitation and temperature projections from the global climate models (GCMs). The projected data are taken from Climate Change Knowledge Portal (CCKP) of the World Bank [23]. Modeled climate projections available on CCKP are derived from the multi-model collection of CMIP6 (Eyring *et al*. 2016). A total of thirty CMIP6-GCMs listed in Table *47*[24] are used. CCKP re-gridded each model output to a common 1x1-degree grid, which was then bias-

[23] Available at https://doi.org/10.57966/b54h-7s87
[24] Available at https://climateknowledgeportal.worldbank.org/netcdf-browser?prefix=data/cmip6-x0.25/

corrected and downscaled the multi-model collection to a common 0.25 x 0.25-degree spatial resolution, as described in Thrasher et al., 2022.

Table 47: The climate models of the Coupled Intercomparison Project Phase 6 (CMIP6) in CCKP

SN	Model name	Institute ID Modeling center/group
1	access-cm2	CSIRO (Commonwealth Scientific and Industrial Research Organization, Australia), and ARCCS (Australian Research Council Centre of Excellence for Climate System Science, Australia
2	access-esm1.5	CSIRO (Commonwealth Scientific and Industrial Research Organization, Australia), and ARCCS (Australian Research Council Centre of Excellence for Climate System Science, Australia
3	bcc-csm2-mr	Beijing Climate Center, China Meteorological Administration, China
4	canesm5	Canadian Centre for Climate Modeling and Analysis, Canada
5	cmcc-esm2	Euro-Mediterranean Center on Climate Change
6	cnrm-cm6-1	Centre National de Recherches Meteorologiques, France
7	cnrm-esm2-1	Centre National de Recherches Meteorologiques / Centre Européen de Recherche et Formation Avancées en Calcul Scientifique, France
8	ec-earth2	EC-Earth-Consortium
9	ec-earth3-veg-lr	EC-Earth-Consortium
10	fgoals-g3	China Academy of Sciences, China
11	gfdl-cm4	Geophysical Fluid Dynamics Laboratory, NOAA, USA
12	gfdl-esm4	Geophysical Fluid Dynamics Laboratory, NOAA, USA
13	giss-e2-1-g	Goddard Institute of Space Studies, NASA, USA
14	hadgem3-gc31-ll	UK Met Office Hadley Centre, U.K.
15	hadgem3-gc31-mm	UK Met Office Hadley Centre, U.K.
16	inm-cm4-8	Institute for Numerical Mathematics, Russia
17	inm-cm5-0	Institute for Numerical Mathematics, Russia
18	ipsl-cm6a-lr	The Institute Pierre Simon Laplace, France
19	kace-1-0-g	National Institute of Meteorological Research, Republic of Korea
20	kiost-esm	Korea Institute of Ocean Science and Technology, Republic of Korea
21	miroc6	Atmosphere and Ocean Research Institute, The University of Tokyo, Japan
22	miroc-es2l	Atmosphere and Ocean Research Institute, The University of Tokyo, Center for Climate system Research - National Institute for Environmental Studies, Japan
23	mpi-esm1-2-hr	Max Planck Institute for Meteorology (MPI-M), Germany
24	mpi-esm1-2-lr	Max Planck Institute for Meteorology (MPI-M), Germany
25	mri-esm2-0	Meteorological Research Institute, Japan
26	nesm3	Nanjing University of Information Science and Technology, China
27	noresm2-lm	Norwegian Climate Centre, Norway
28	noresm2-mm	Norwegian Climate Centre, Norway
29	taiesm1	Research Center for Environmental Changes, Academia Sinica, Taiwan
30	ukesm1-0-ll	U.K.'s Met Office and Natural Environment Research Council (NERC), U.K.

From CCKP, the global dataset of different climate variables is extracted and the projected timeseries are extracted at the Bunakha catchment scale. The future projections are divided into three-time windows: **NF (near future: 2020-2039), MF (mid future: 2040-2059), and FF (far future: 2060-2079)** on the basis of CCKP's future period classification.

The median value across individual model projections is used as the primary representation of the ensemble, with additional metrics at the 90th (high) and 10th (low) percentiles to illustrate the range of possible outcomes. These values highlight the uncertainty caused by different climate sensitivities and internal climate variability across models.

A summary of the climate change projection trends is shown in Box 6.

Box 6: Summary of climate change projection trends for the Bunakha HPP region

Projected precipitation trend: increasing; the Wangchuu basin may become wetter overall (drier winters and wetter summers)

Temperature trend: warming

Future extremes trend (extreme rainfall events): increasing

Streamflow trend: increasing

Sediment trend: landslides and debris flows increasing, transporting a massive amount of sediment

9.3.2.1 Precipitation

Table 48 shows the projected changes (%) in annual and seasonal precipitation across the basin in near, mid, and far future under two SSPs (245 and 585[25]). The annual precipitation projections indicate **a consistent and increasing trend in future rainfall for the region** (Figure 49 and Figure 50), particularly under the high-emissions SSP 585 scenario. Under SSP 585 scenario, ensemble median projection shows slight increase of 0.5% in the near future, rising to a 4.9% and 10.0% increase in the mid future and far future, respectively. While the ensemble median values provide a likely future trajectory, it is crucial to consider the wide range of uncertainty represented by the 10th and 90th-percentiles of the CMIP6 GCM Ensemble. Even though the median annual precipitation in the far future under SSP 585 shows a 10% increase, the 10th-percentile suggests a potential decrease of -17.5%, while the 90th-percentile indicates a possible increase of over 41%. Overall, a wetter climate is the most likely outcome, although a drier future cannot be ruled out. This uncertainty is a key aspect of climate projections and emphasizes that future planning must consider a broad spectrum of possible changes, not just the most probable median value.

At seasonal scale (Table 48), monsoon season is projected to undergo the most substantial changes, with ensemble median projection increasing by 0% [1.1%] in the near future under SSP 245 [585], rising to 3.4% [5.8%] in the mid future, and 4.8% [11.9%] in the far future. In contrast, the winter season is expected to experience a consistent decreasing trend, with median

[25] SSP245 (also SSP 2-4.5) is a mid-range climate change scenario representing a middle-of-the-road" socioeconomic future combined with a moderate level of greenhouse-gas emissions. SSP585 (also SSP5-8.5) is the highest-emissions, "fossil-fueled development" climate scenario. It represents a world with rapid economic growth driven by intensive fossil-fuel use, leading to extremely high greenhouse-gas concentrations. (https://www.dkrz.de/en/communication/climate-simulations/cmip6-en/the-ssp-scenarios?utm). See Terminology at the onset of this ESIA Report for further details on the meaning of SSP.

precipitation projected to decline under both scenarios. Under SSP 245 [585], the decrease is similar, dropping from a median of -9.3% [-8.8%] in the near future to -10.2% [-9.5%] in the far future. **In overall, the Wangchhu basin may become wetter overall, and is likely to experience drier winters and wetter summers.**

The spatial distribution of relative change in precipitation (ensemble median projection) at seasonal scale are shown from Figure *51* to Figure 58. Both SSP scenarios show a similar magnitude and spatial variability of relative change in winter precipitation across all time windows (Figure *51* and Figure *55*). In case of monsoon under SSP 585, precipitation is projected to increase with similar spatial variability throughout the basin, particularly during far future (Figure *53* and Figure 57).

Table 48: Projected changes (%) in precipitation in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios

		SSP 245 (mid-range)[25]			SSP 585 (highest-emissions)[25]		
		10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
Annual	NF	-21.3	-0.4	24.4	-21.0	0.5	23.5
	MF	-20.3	2.2	26.2	-20.6	4.9	30.2
	FF	-19.9	3.7	31.8	-17.5	10.0	41.5
DJF	NF	-35.2	-9.3	18.5	-36.5	-8.8	17.1
	MF	-36.8	-9.6	16.8	-39.1	-8.5	18.0
	FF	-40.6	-10.2	18.0	-40.3	-9.5	17.1
MAM	NF	-18.7	3.3	29.6	-18.4	4.2	30.0
	MF	-19.0	5.1	31.1	-20.9	7.3	34.5
	FF	-20.7	5.7	34.0	-19.3	8.8	37.5
JJAS	NF	-18.8	0.0	21.3	-18.3	1.1	21.3
	MF	-17.5	3.4	24.0	-17.6	5.8	27.7
	FF	-15.9	4.8	31.1	-14.4	11.9	44.0
ON	NF	-26.8	-1.8	31.3	-26.3	-1.7	27.1
	MF	-24.8	-0.3	32.4	-23.7	4.4	38.4
	FF	-24.4	3.2	36.5	-17.2	11.6	45.6

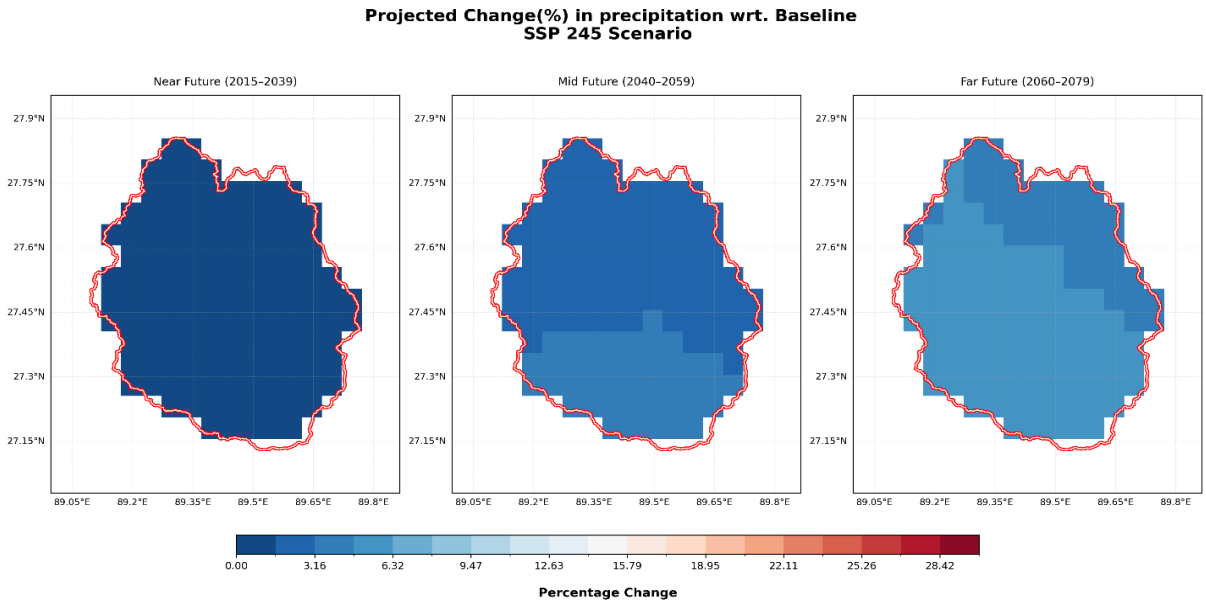


Figure 49: Spatio-temporal variation of relative change in average annual precipitation (ensemble median) under SSP 245

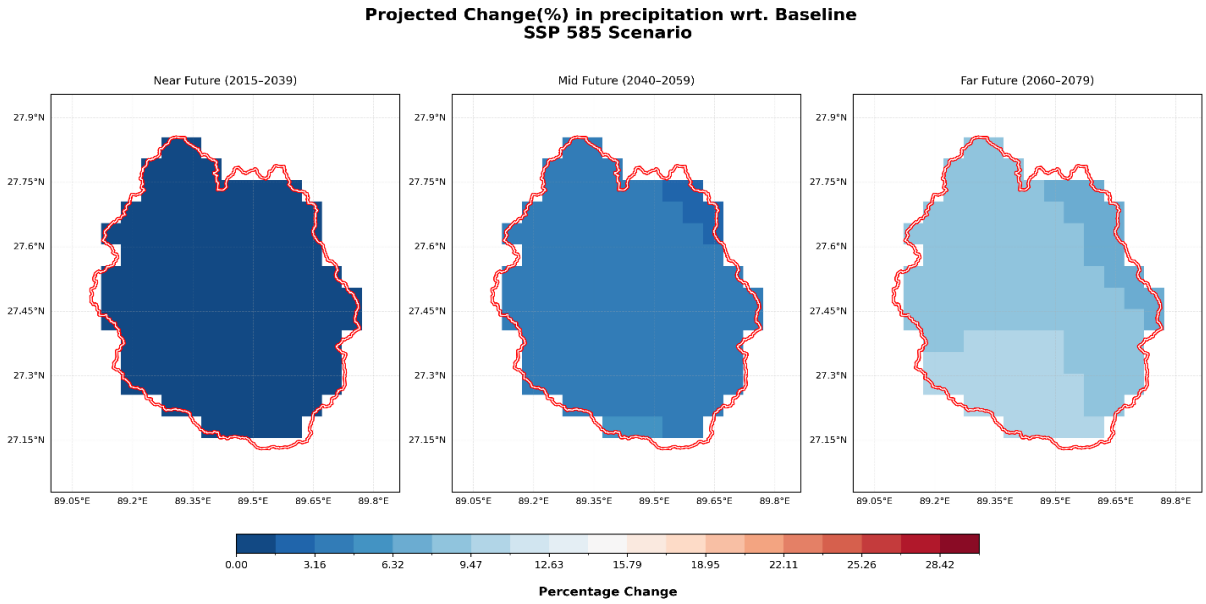


Figure 50: Spatio-temporal variation of relative change in average annual precipitation (ensemble median) under SSP 585

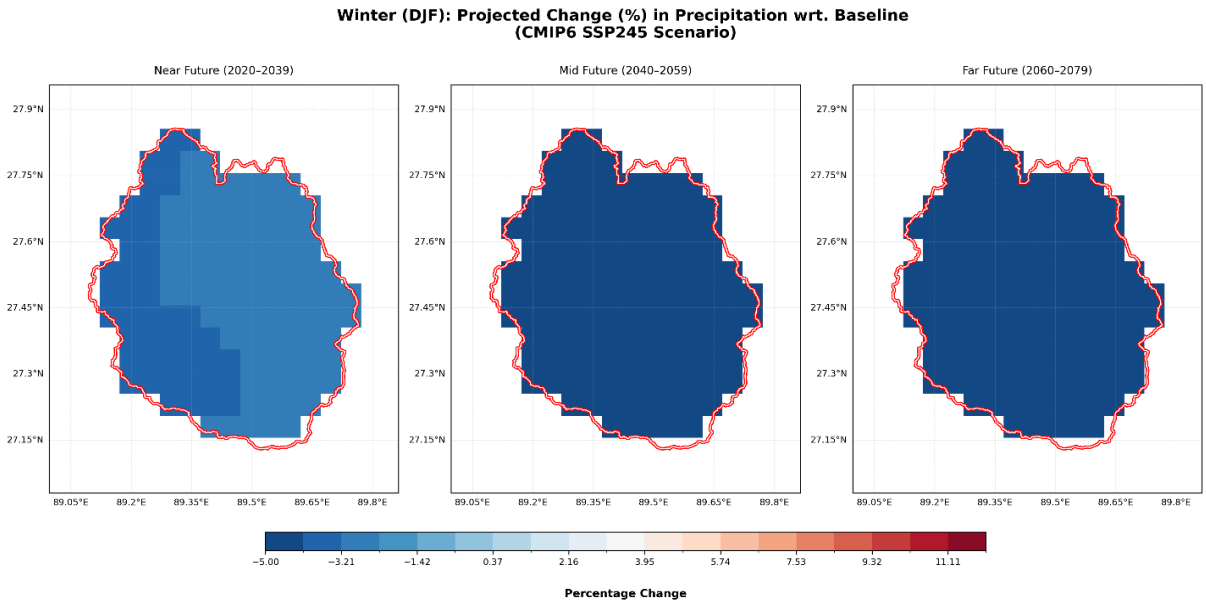


Figure 51: Spatio-temporal variation of relative change in winter (DJF) precipitation (ensemble median) under SSP 245

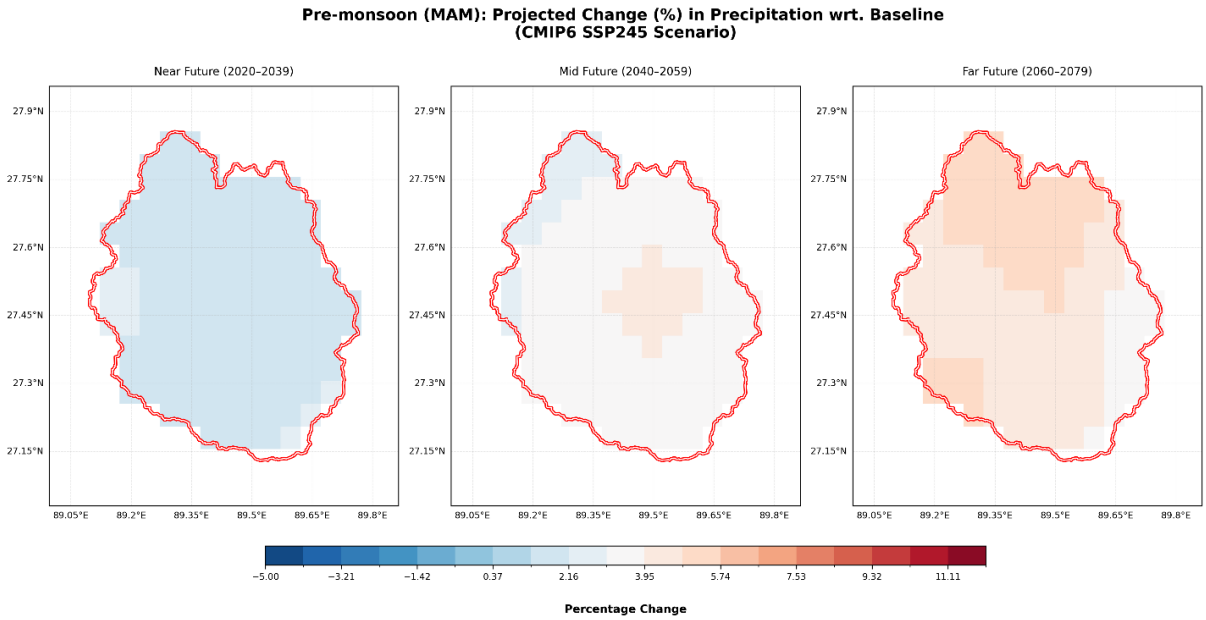


Figure 52: Spatio-temporal variation of relative change in Pre-monsoon (MAM) precipitation (ensemble median) under SSP 245

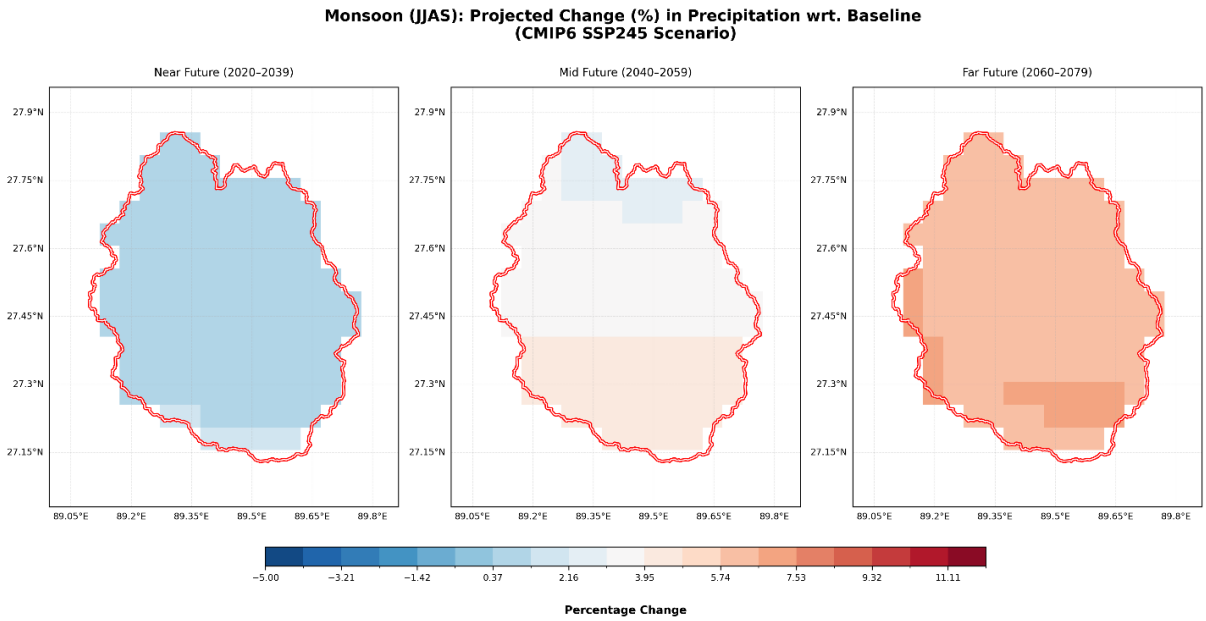


Figure 53: Spatio-temporal variation of relative change in monsoon (JJAS) precipitation (ensemble median) under SSP 245

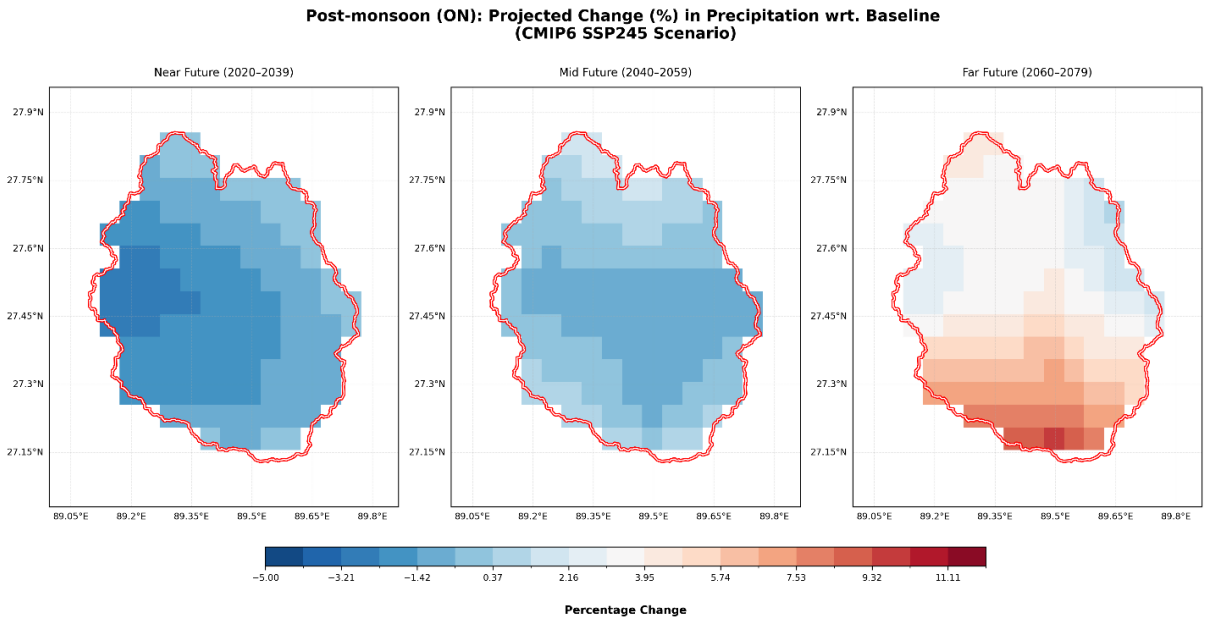


Figure 54: Spatio-temporal variation of relative change in post-monsoon (ON) precipitation (ensemble median) under SSP 245

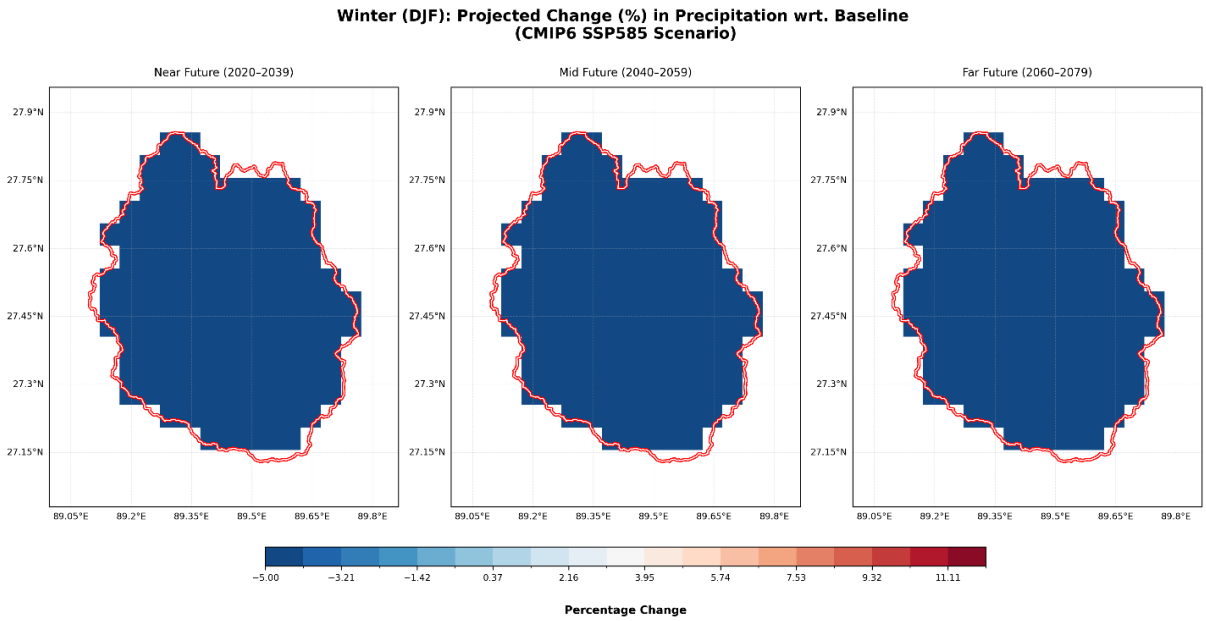


Figure 55: Spatio-temporal variation of relative change in winter (DJF) precipitation (ensemble median) under SSP 585

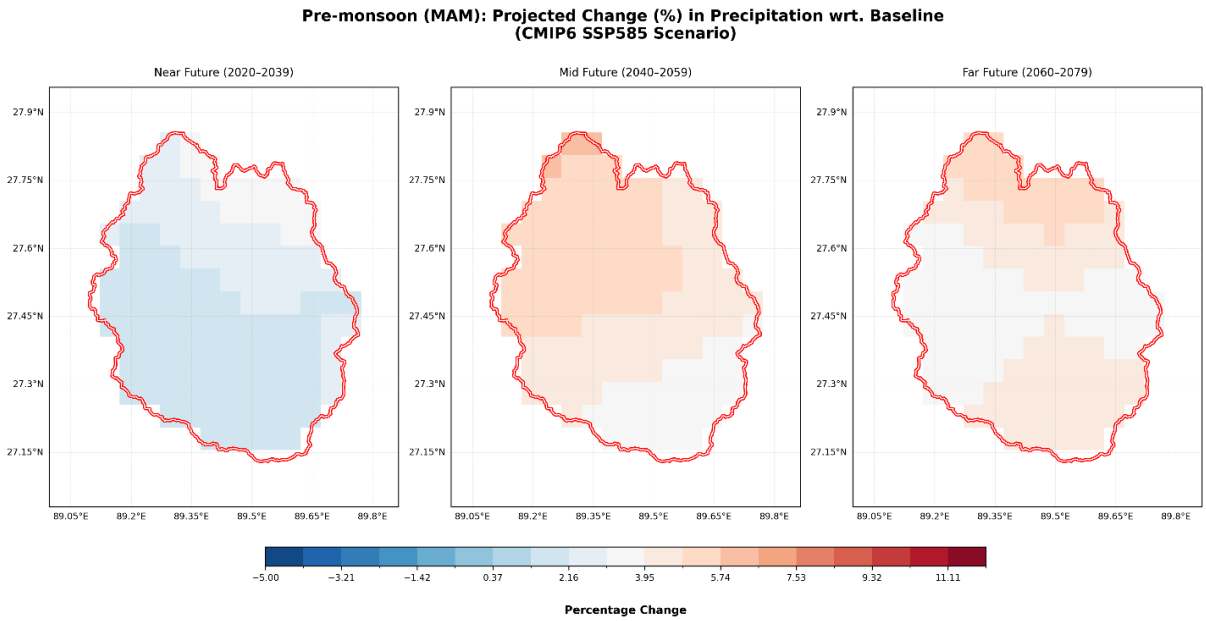


Figure 56: Spatio-temporal variation of relative change in pre-monsoon (MAM) precipitation (ensemble median) under SSP 585

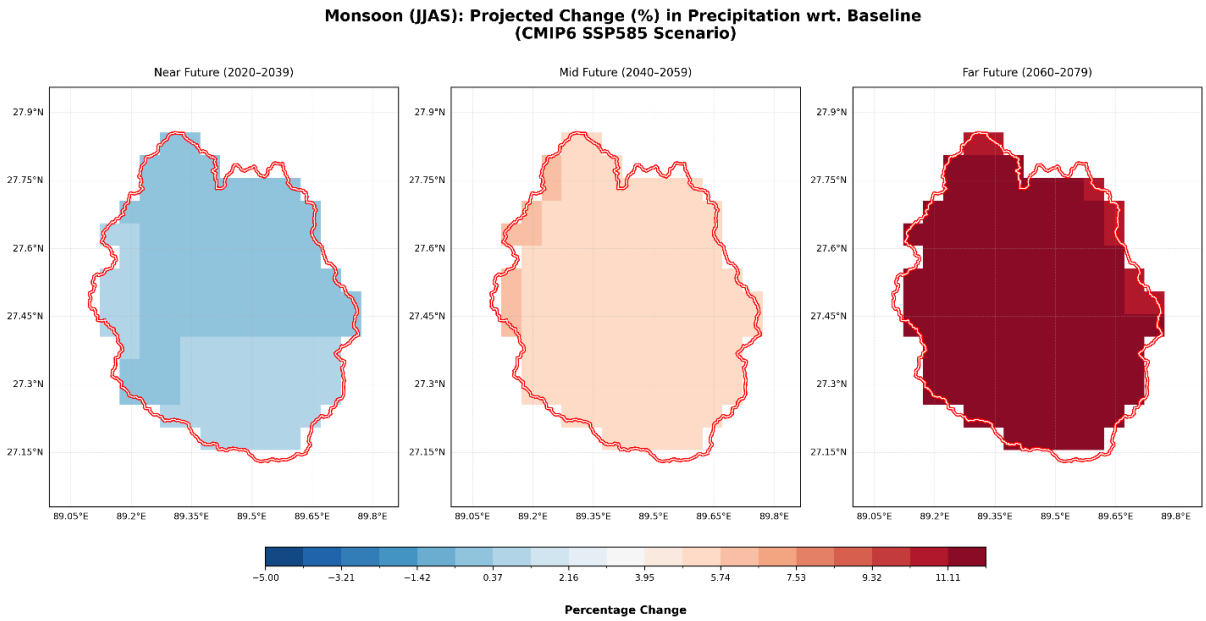


Figure 57: Spatio-temporal variation of relative change in monsoon (JJAS) precipitation (ensemble median) under SSP 585

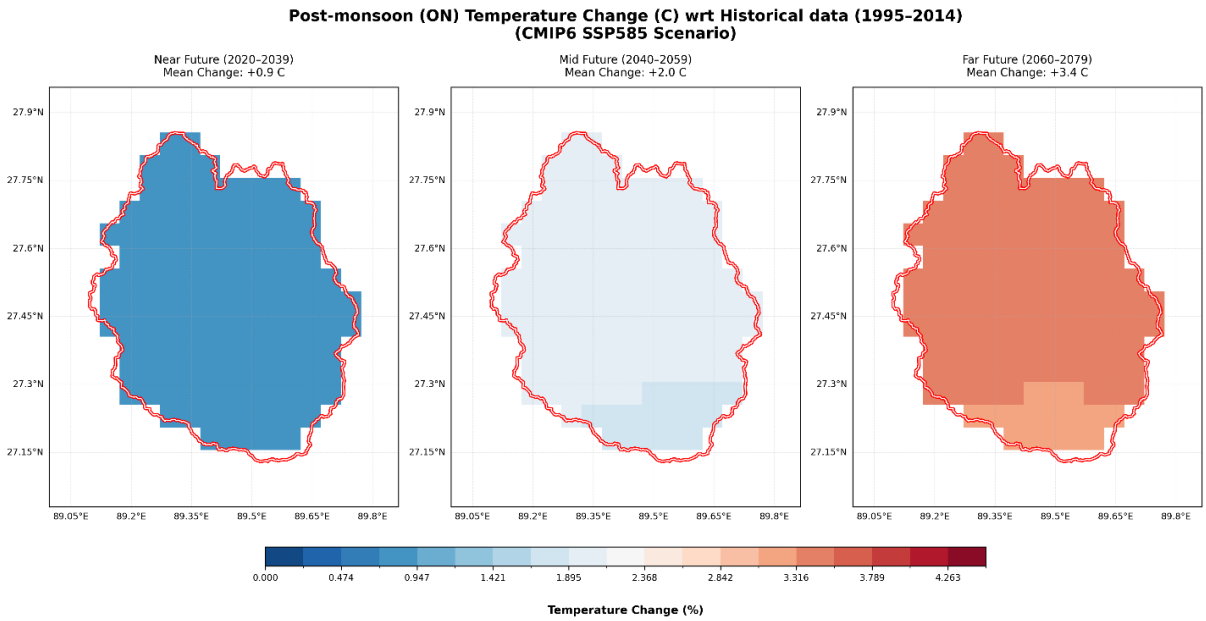


Figure 58: Spatio-temporal variation of relative change in post-monsoon (ON) precipitation (ensemble median) under SSP 585

9.3.2.2 Temperature

Table 49 shows the projected changes (°C) in annual and seasonal average temperature across the basin in near, mid, and far future under two SSPs. The annual projections indicate a **continuous and accelerated warming trend for the Wangchhu region** across all future periods and both SSP scenarios (Figure *59* and Figure *60*). Under SSP 245 [585] scenario, the median annual average temperature is projected to increase by 1.0°C [1.1°C] in the near future, 1.7°C [2.2°C] in the mid future, and 2.3°C [3.5°C] in the far future.

The spatial variability of projected change (°C) under two SSPs in three future periods are shown from Figure *61* to Figure *68*. The warming is not uniform throughout the year, with some seasons experiencing more drastic temperature increases than others. In the far future, SSP 585 scenario shows that the winter season is projected to warm the most, with ensemble median increase of 4.0°C. The monsoon season follows with a projected increase of 3.0°C, while the pre-monsoon and post-monsoon seasons are expected to warm by 3.4°C and 3.6°C, respectively. A similar but less severe pattern is observed under the SSP 245 scenario. The pronounced warming during the winter months (Figure *61* and Figure *65*) could have significant implications for the region, including reduced snowpack and changes in the hydrological cycle.

The future temperature projections are subject to a degree of uncertainty, which is represented by the ensemble 10th and 90th-percentile values. For the far future under SSP 245, the median annual temperature increase of 2.3°C has a range from 1.3°C (10th-percentile) to 3.4°C (90th-percentile). The uncertainty is more significant under the SSP 585 scenario, where the median annual increase of 3.5°C has a wider range from 2.3°C to 4.9°C. This wide spread of outcomes, particularly in the SSP 585, demonstrates the complexity in GCM model and highlights the different possibilities for future warming.

Based on three CMIP5 regional climate models; ACCESS, CNRM-CM5, and MPI-ESM-LR, Zam et al. (2021) generated temperature projections under two RCP scenarios. They also projected a significant temperature increase for the Wangchhu basin, with a rise of 1.5°C under RCP 4.5 and 3.6°C under RCP 8.5 for the far future, which is similar to the ensemble median projection of 2.3°C and 3.67°C projected for the similar climate change scenarios in CMIP6 represented by SSP 245 and SSP 585 (Table 49).

The projected temperature increases can have significant implications for the region's water resources, directly impacting the hydrological cycle of the Wangchhu basin. Furthermore, the evaporation loss from the reservoir may increase under projected higher temperature.

Table 49: Projected changes (°C) in average temperature in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios

		SSP 245			SSP 585		
		10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
Annual	NF	0.2	1.0	1.8	0.2	1.1	2.0
	MF	0.9	1.7	2.7	1.2	2.2	3.3
	FF	1.3	2.3	3.4	2.3	3.5	4.9
DJF	NF	0.1	1.1	2.2	0.0	1.3	2.6
	MF	0.9	1.5	2.2	1.2	1.9	2.8
	FF	1.4	2.6	4.0	2.5	4.0	5.7
MAM	NF	0.0	0.9	1.9	0.1	1.0	1.9
	MF	0.8	1.7	2.7	1.1	2.2	3.3

		SSP 245			SSP 585		
		10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
	FF	1.3	2.2	3.3	2.3	3.4	4.7
JJAS	NF	0.3	0.8	1.3	0.4	0.9	1.4
	MF	0.9	1.5	2.2	1.2	1.9	2.8
	FF	1.2	1.9	2.8	2.1	3.0	4.1
ON	NF	0.3	1.0	1.8	0.4	1.1	2.0
	MF	1.0	1.7	2.7	1.4	2.3	3.5
	FF	1.3	2.3	3.3	2.3	3.6	5.0

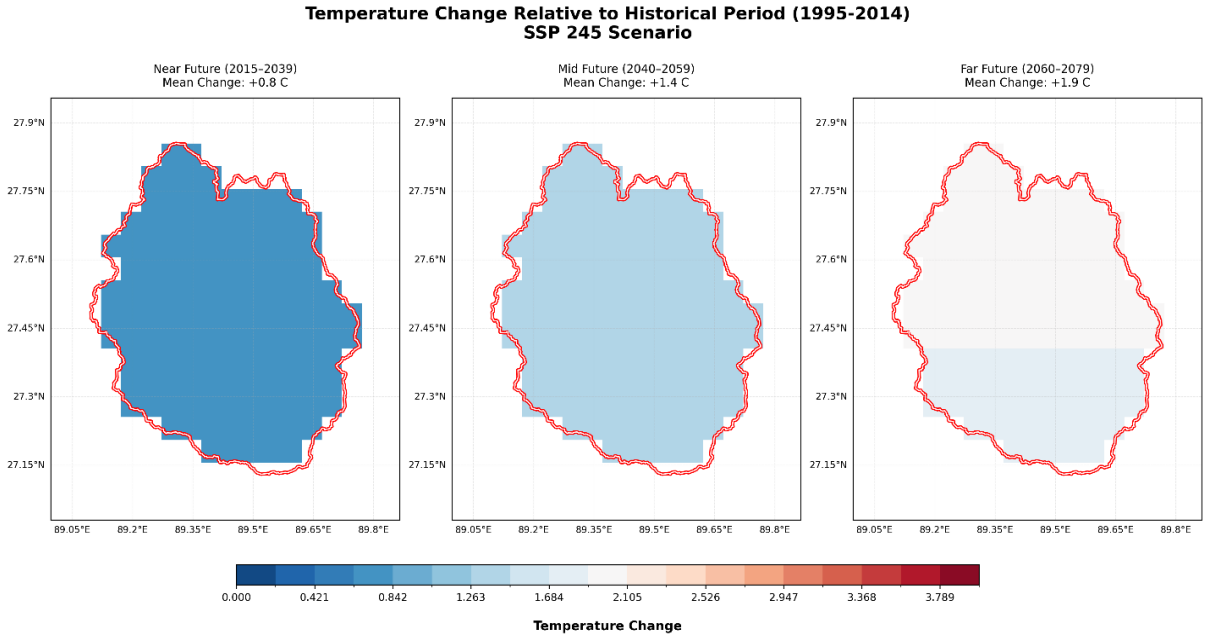


Figure 59: Spatio-temporal variation of change (°C) in average annual temperature (ensemble median) under SSP 245

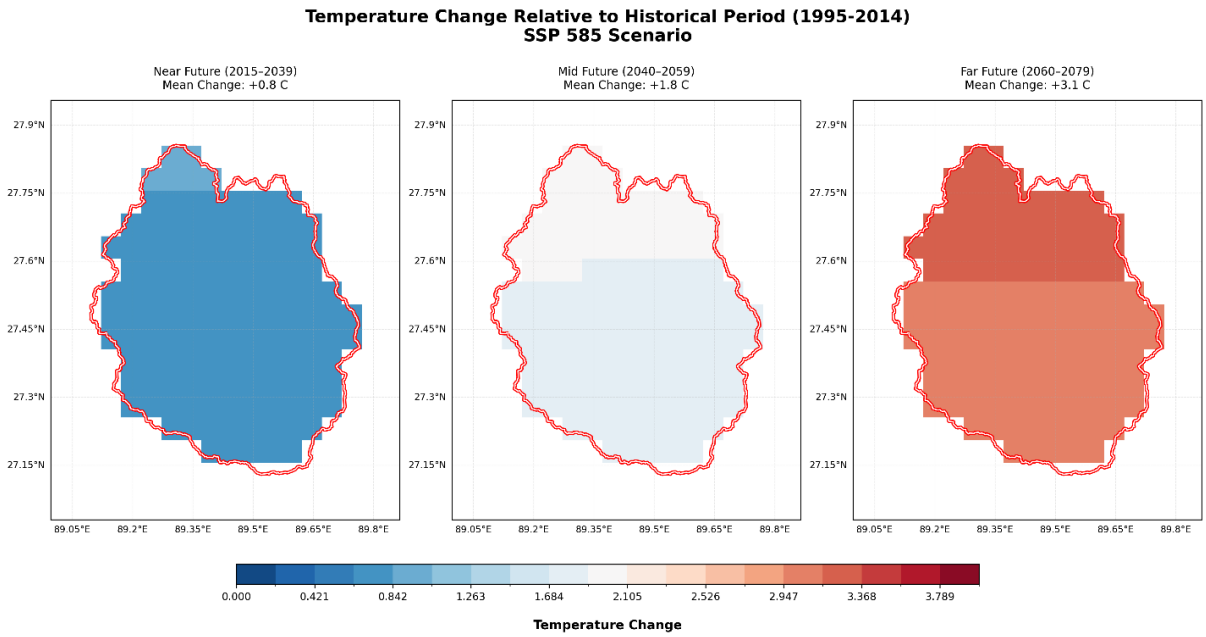


Figure 60: Spatio-temporal variation of change (°C) in average annual temperature (ensemble median) under SSP 585

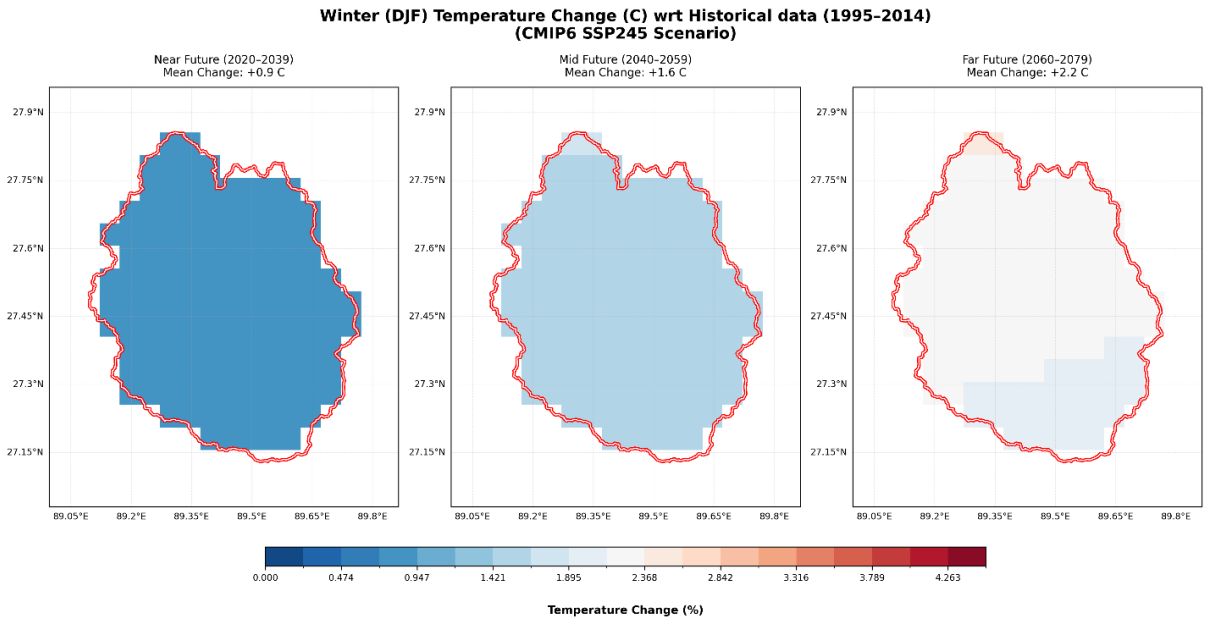


Figure 61: Spatio-temporal variation of change (°C) in winter (DJF) temperature (ensemble median) under SSP 245

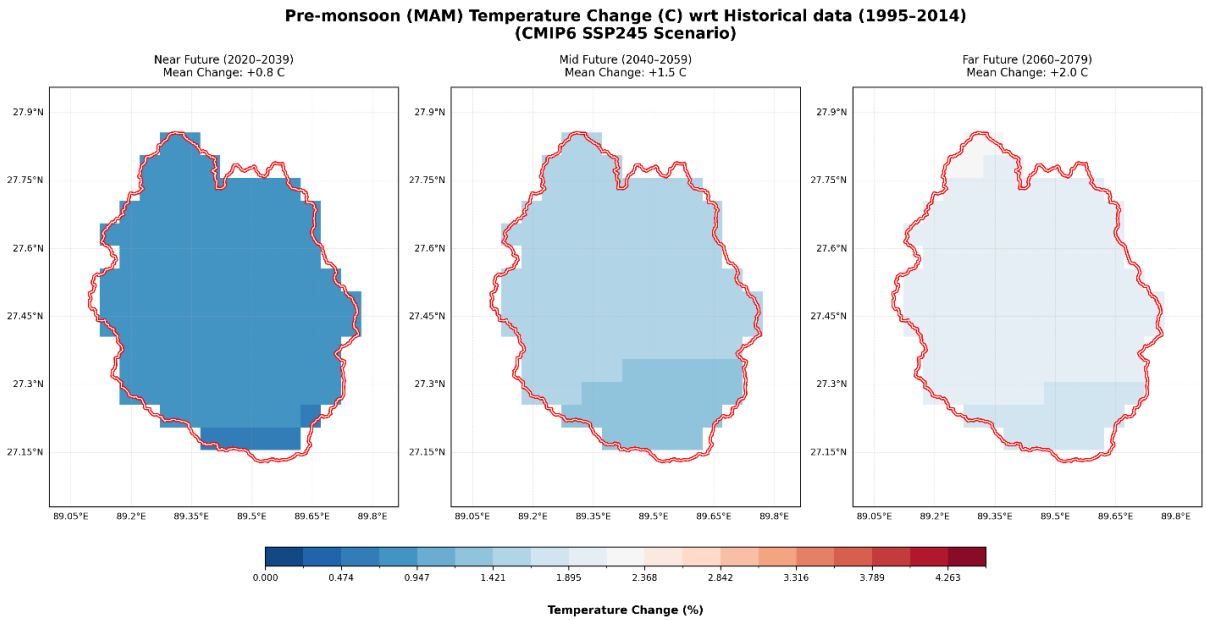


Figure 62: Spatio-temporal variation of change (°C) in pre-monsoon (MAM) temperature (ensemble median) under SSP 245

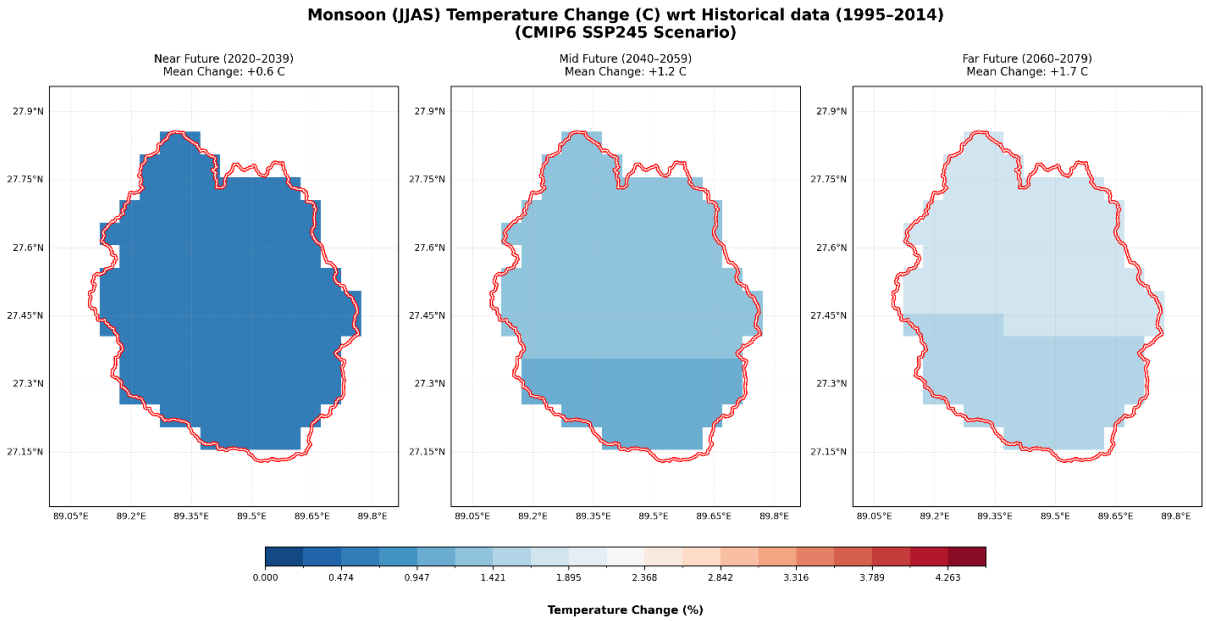


Figure 63: Spatio-temporal variation of change (°C) in monsoon (JJAS) temperature (ensemble median) under SSP 245

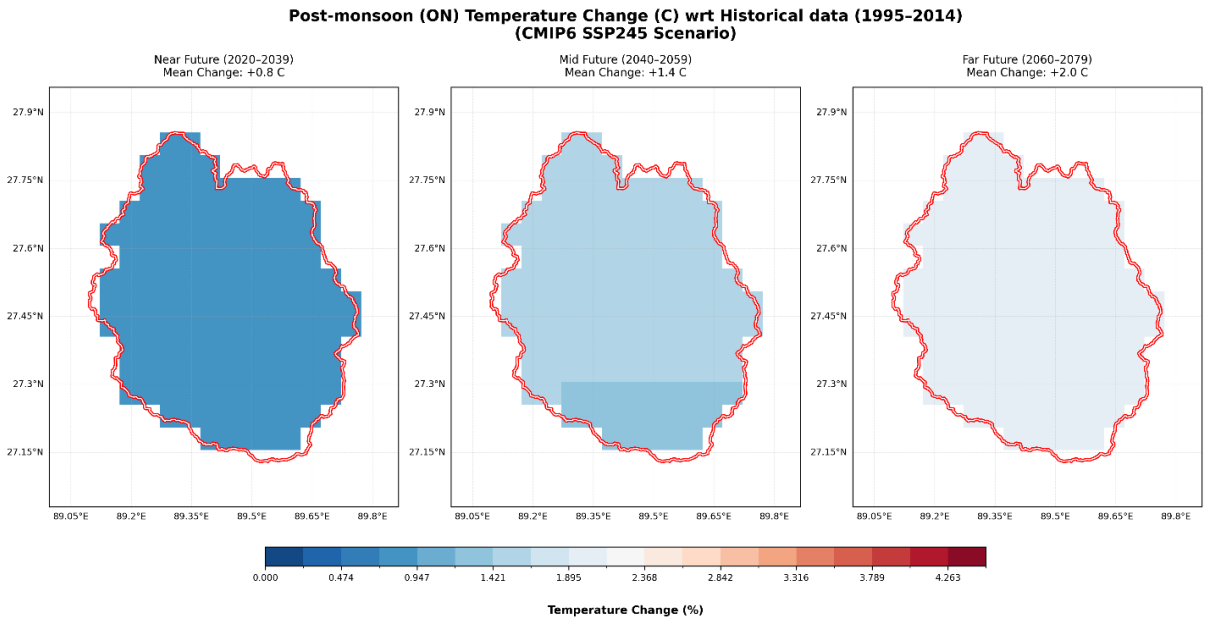


Figure 64: Spatio-temporal variation of change (°C) in post-monsoon (ON) temperature (ensemble median) under SSP 245

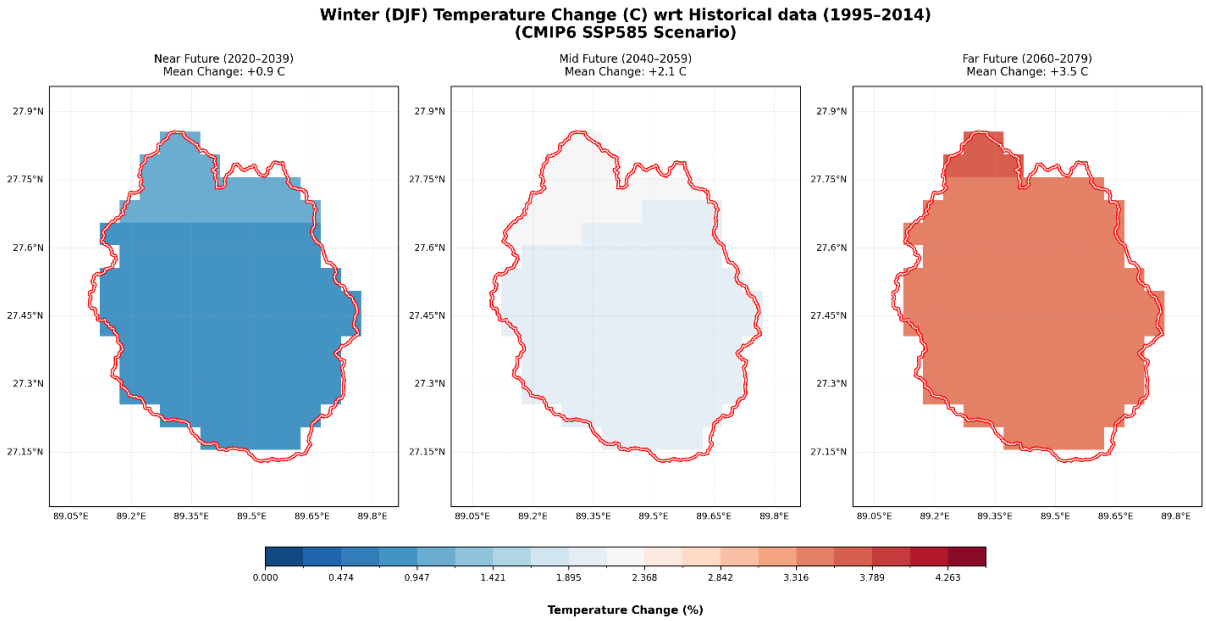


Figure 65: Spatio-temporal variation of change (°C) in winter (DJF) temperature (ensemble median) under SSP 585

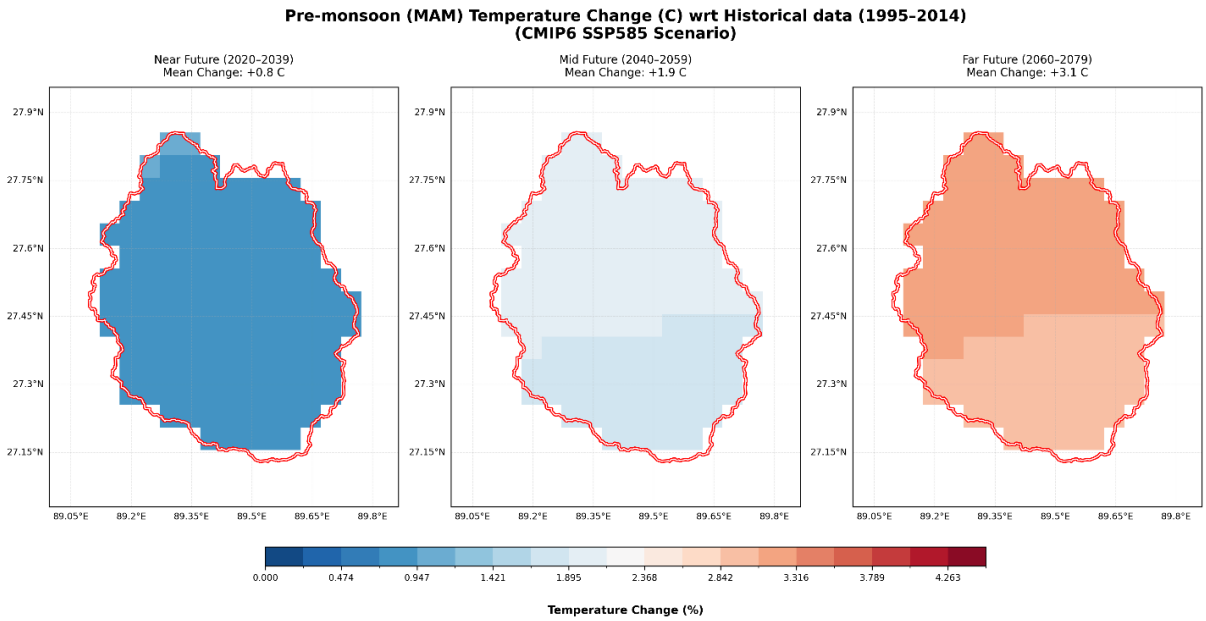


Figure 66: Spatio-temporal variation of change (°C) in pre-monsoon (MAM) temperature (ensemble median) under SSP 585

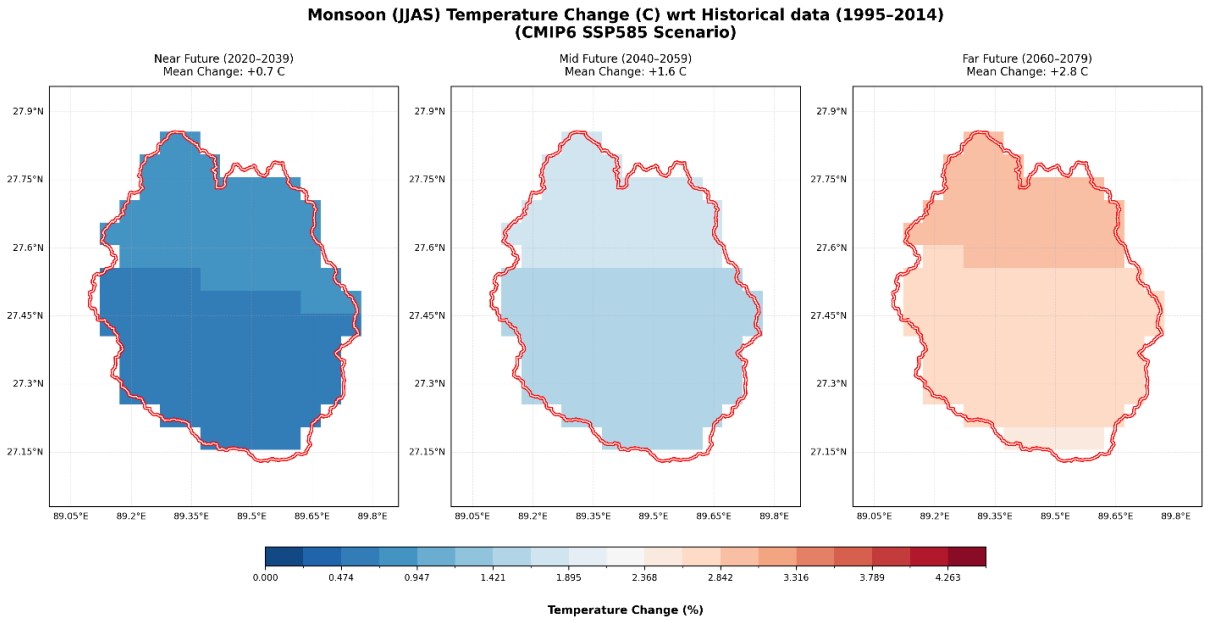


Figure 67: Spatio-temporal variation of change (°C) in monsoon (JJAS) temperature (ensemble median) under SSP 585

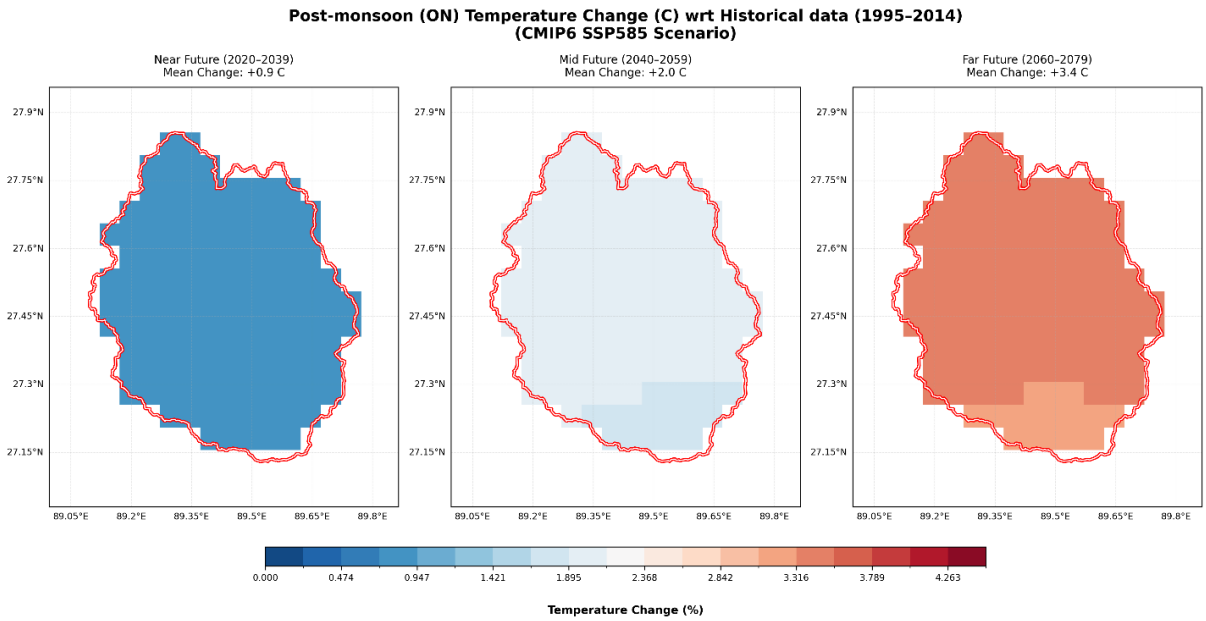


Figure 68: Spatio-temporal variation of change (°C) in post-monsoon (ON) temperature (ensemble median) under SSP 585

9.3.2.3 Future extremes

RX1day is the highest 1-day period precipitation amount during each data period. RX5day is the highest 5-day precipitation amount over a consecutive 5-day period during each data period. CMIP6 projections (Table *50*) shows an increasing trend in the future, with higher rate under SSP 585. Future projection (Figure *69* to Figure *72*) shows a **clear and concerning increase in the intensity of extreme rainfall events for the Wangchhu basin**. Under SSP 585 scenario, the ensemble median projection for RX1day indicates an increase of 5.3% in the near future, a rise to 14.2% in the mid future, and a substantial 25% increase in the far future. The trend for RX5day is similar, with ensemble median increase of 22.3% projected for the far future. The spatial variability of projection shows that the southern region of basin is likely to experience intensified rainfall extremes, particularly during far future. This trend suggests that the basin is likely to experience more intense, high-volume rainfall events in the future, leading to a higher risk of flash floods and riverine flooding.

The projections for extreme precipitation, come with a degree of uncertainty. For the far future under SSP 585 scenario, the ensemble median projected increase in RX1day is 25%, but the full range of projections from the ensemble 10th to 90th-percentiles is from -18.1% to 82.5%. Similarly, the RX5day ensemble median increase of 22.3% has a wide range, spanning from -17.7% to 85.3%. This widespread in the projections highlights the difficulty in modeling extreme weather events by different climate models. The significant upper end of these ranges indicates that there is a considerable possibility that the actual increase in precipitation intensity could be far more severe than the ensemble median projection, a crucial factor to consider for robust risk management.

Table 50: Projected changes (%) in extremes in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios

		SSP 245			SSP 585		
		10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
RX1day	NF	-29.9	1.7	49.4	-28.1	5.3	51.1
	MF	-24.4	6.9	49.0	-23.8	14.2	63.2
	FF	-22.7	12.0	66.9	-18.1	25.0	82.5
RX5day	NF	-27.3	1.4	48.1	-25.9	4.0	51.5
	MF	-22.9	10.2	54.4	-23.5	10.8	65.6
	FF	-21.8	12.8	66.2	-17.7	22.3	85.3

With the future projections indicating an increase, there is a clear implication of an intensified hydrological cycle. From a design perspective, headworks component, such spillways and floodwall, needs to be designed to handle higher and more frequent flood events.

In Bagmati river basin of central Himalaya, D. Shrestha et al. (2023) found that the historical RX1day 100-year return period rainfall will become a 20 or 25-year return period rainfall. As a result, the historical 100-year return period flood discharge will correspond to a 25-year return period future flood. Similar increment projection and implication are likely to be translated in the case of Bunakha dam site, Wangchhu basin. From an operational standpoint, the shift towards a much wetter monsoon season could lead to increased power generation and rapid reservoir filling beneficial for dry month, but also pose a challenge for flood control and sediment management. Also, the wide uncertainty range in the projections means that hydropower planning must not rely solely on the ensemble median. It is crucial to develop robust operational plans and adaptive management strategies that can account for a broad spectrum of possible outcomes.

The increase in extreme precipitation poses a threat to dam projects and potential cascading vulnerability throughout the Wangchhu basin. Existing dam infrastructures may be undersized and unable to safely manage such extreme flow. An integrated, basin-wide flood management plan with coordinated operational protocols among all projects is essential to mitigate these risks and ensure the safety and security of the entire river system.

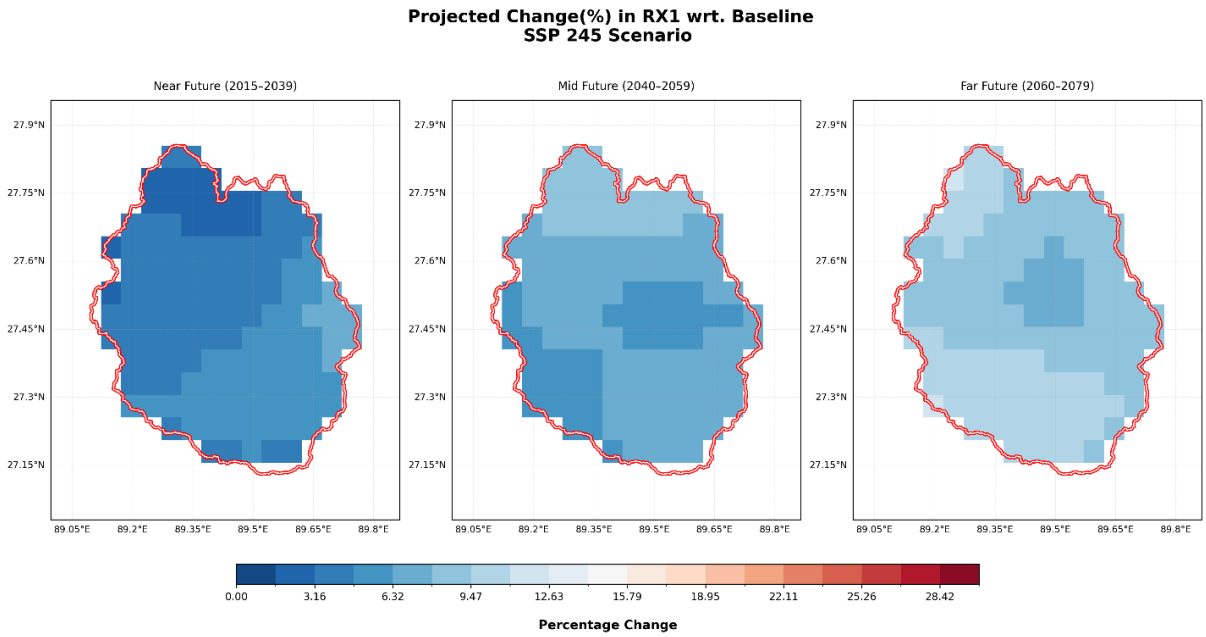


Figure 69: Spatio-temporal variation of relative change in RX1day (ensemble median) under SSP 245

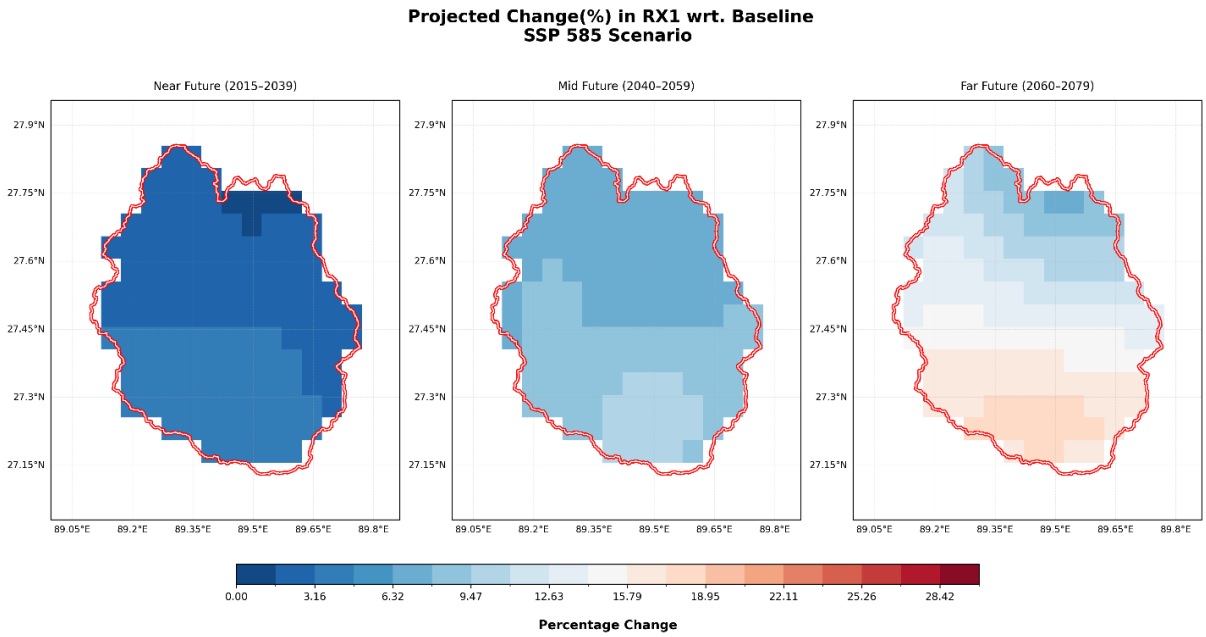


Figure 70: Spatio-temporal variation of relative change in RX1day (ensemble median) under SSP 585

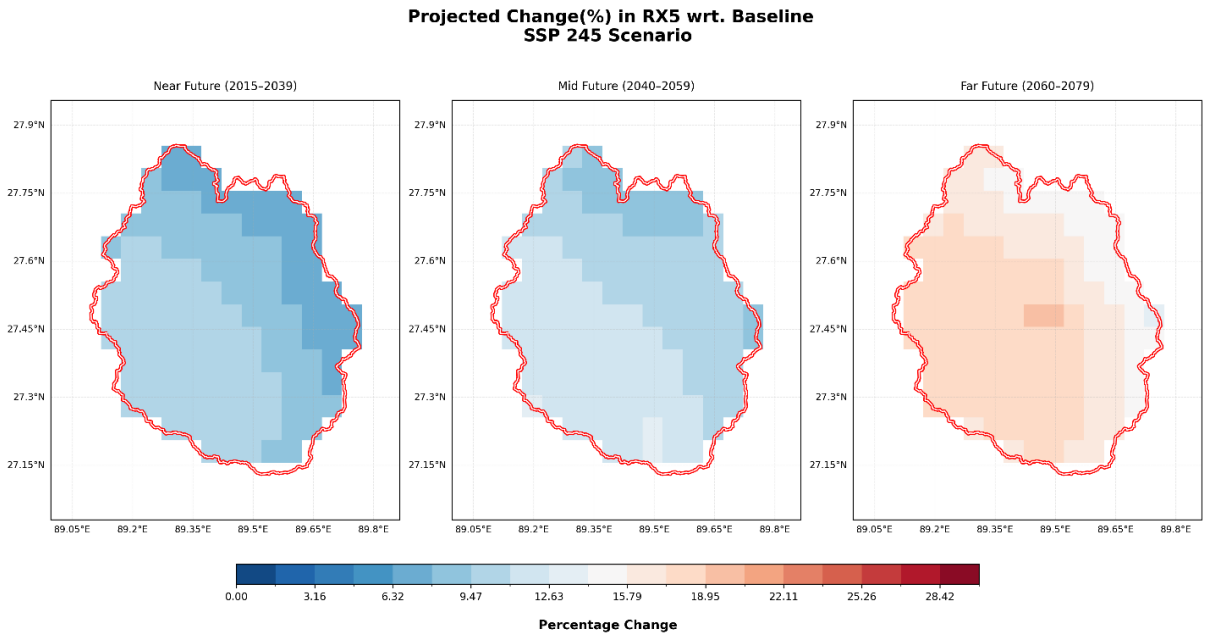


Figure 71: Spatio-temporal variation of relative change in RX5day (ensemble median) under SSP 245

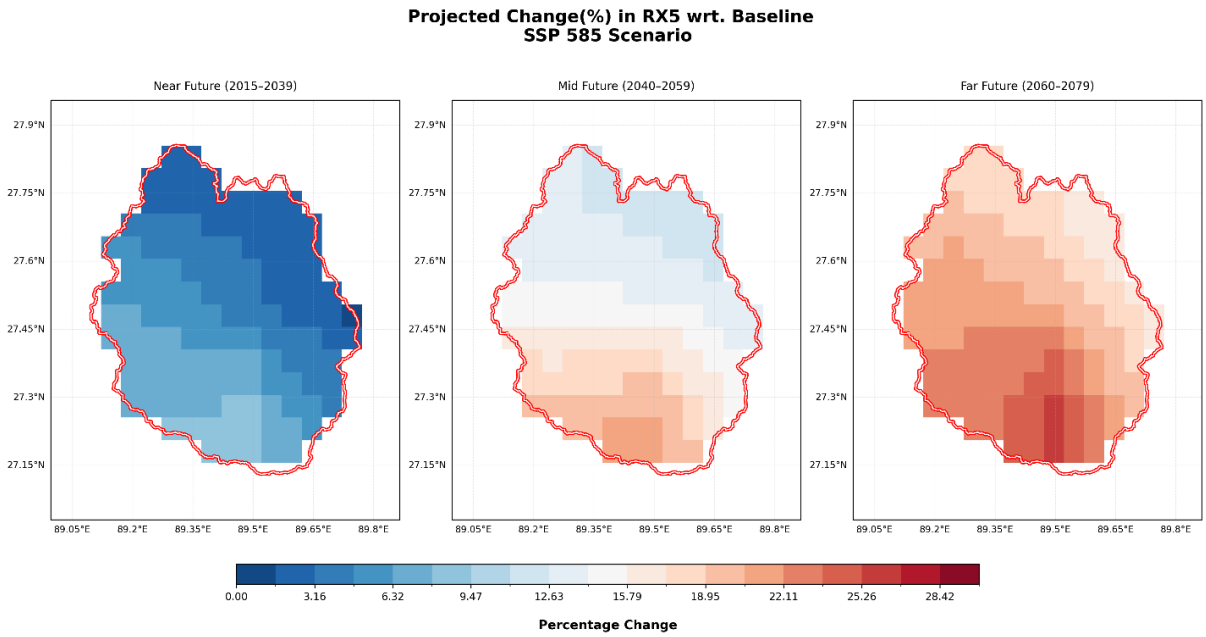


Figure 72: Spatio-temporal variation of relative change in RX5day (ensemble median) under SSP 585

9.3.2.4 Streamflow

The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) was used to generate streamflow projections for the Wangchhu basin, Bhutan, under current and future climatic conditions. SWAT has been extensively used in Himalayan river basins for various hydrologic applications, including climate change impact assessment and water resources management (Bhatta et al., 2019; Garee et al., 2017; Marahatta et al., 2021; Pandey et al., 2020; Zam et al., 2021). SWAT is a physically-based semi-distributed model which can simulate hydrological

processes, plant growth, sediment transport, and nutrient yield under dynamic environmental conditions such as land use, soil, and climate (Neitsch et al., 2011).

Figure 73 and Figure 74 show the comparison of the simulated and observed streamflow at daily and monthly hydrographs, respectively for the calibration (2001-2014) and validation (2015-2023) periods. The model performance at the Chhukha dam station indicates an acceptable level of accuracy (Moriasi et al., 2007), with both the NSE and R^2 values greater than 0.71 during the calibration and validation periods. However, underestimation bias is observed at the station, with a PBIAS greater than 15% over the validation period.

Period	NSE	R2	PBIAS
Calibration	0.71	0.73	10.5
Validation	0.74	0.80	17.9

Furthermore, an R^2 value greater than 0.7 for both calibration and validation periods indicates that the timing of the simulated hydrograph is reasonable. The daily simulation time step and continuous-time marching limit the application of the SWAT model for a detailed, event-based peak flow simulation (Bhatta et al., 2020). Overall, the model demonstrates satisfactory performance during both the calibration and validation periods.

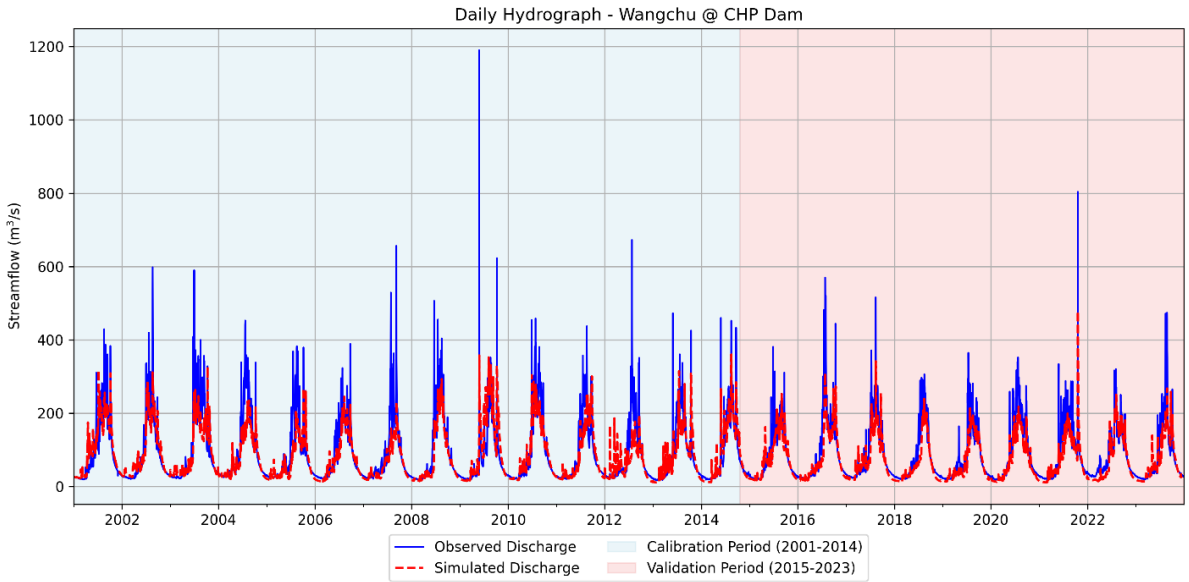


Figure 73: Comparison of hydrograph based on observed and simulated daily flow timeseries at Chhukha dam station

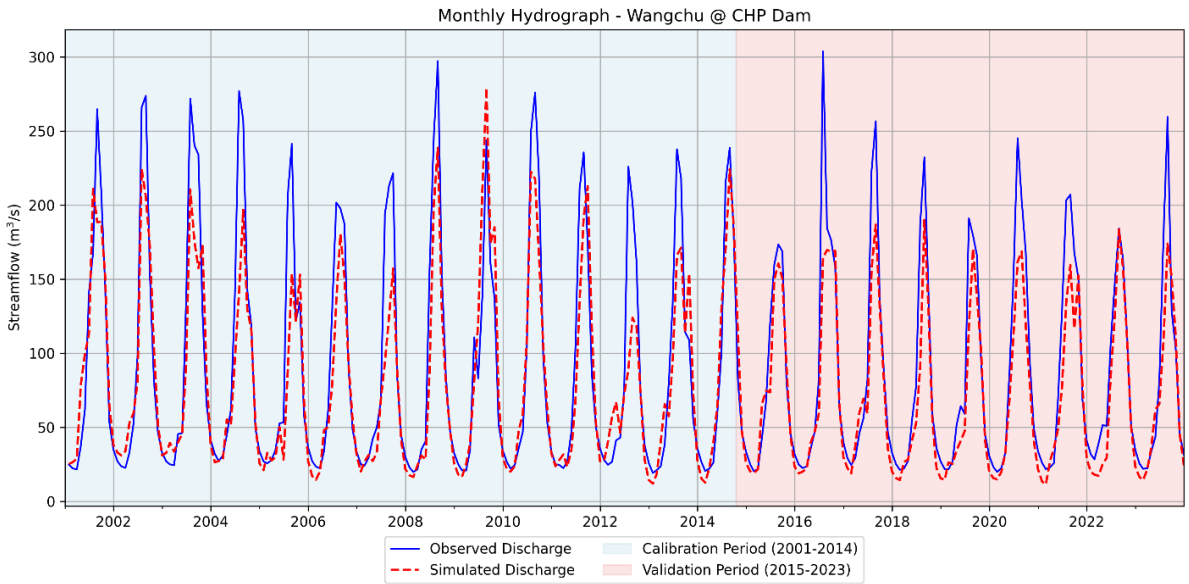


Figure 74: Comparison of hydrograph based on observed and simulated monthly flow timeseries at Chhukha dam station

Future Streamflow at Bunakha Dam

The calibrated SWAT model is run with the plausible future climate data prepared by adjusting the projected change in daily precipitation (Table 48) and temperature (Table 49) under CMIP6 scenarios. Under climate change, projected increase in temperature and precipitation translates to the alteration in future water availability at Bunakha dam (Table 51).

At annual scale, ensemble median of streamflow projections at the Bunakha dam shows an increasing trend over time under both SSP scenarios. Under SSP 245 [585], the ensemble median indicates the increment up to 0.36% [1.34%] in the near future (2020-2039), rising to 3.56% [6.27%] in the mid future (2040-2059) and 5.09% [12.14%] in the far future (2060-2079). These projections suggest that **the Bunakha dam will likely experience higher overall streamflow**.

Seasonal projections reveal a shift toward a much wetter monsoon season. Under SSP 585, the median streamflow is expected to increase by 12.83% in the far future, indicating a significantly more energetic monsoon season. However, the winter season shows a more complex pattern. While the ensemble median change is a decrease of -1.22% in the near future under SSP 245, this turns into an increase of 10.9% in the far future under SSP 585. Pre-monsoon and post-monsoon seasons also show increasing trends, with the ensemble median streamflow under SSP 585 increasing by 9.7% and 12.2% respectively in the far future.

Table 51: Projected changes (%) in streamflow in near future (NF: 2015-2039), mid future (MF: 2040-2059) and far future (FF: 2060-2079) under different climate change scenarios

		SSP 245			SSP 585		
		10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
Annual	NF	-19.6	0.4	24.2	-19.1	1.3	23.9
	MF	-18.3	3.6	27.0	-18.6	6.3	31.2
	FF	-17.4	5.1	33.5	-15.1	12.1	44.7
DJF	NF	-21.7	-1.2	23.4	-21.3	-0.3	22.8
	MF	-20.1	2.1	26.3	-20.2	5.0	30.6
	FF	-19.4	3.7	32.0	-16.0	10.9	40.5
MAM	NF	-20.9	1.9	29.2	-20.6	2.9	29.4
	MF	-20.7	4.2	31.1	-22.2	6.5	35.1
	FF	-21.5	5.0	35.5	-19.7	9.7	41.4
JJAS	NF	-19.5	0.3	23.4	-19.0	1.4	23.5
	MF	-18.2	3.8	26.5	-18.5	6.4	30.7
	FF	-16.9	5.2	34.0	-15.1	12.8	47.2
ON	NF	-18.1	0.1	23.4	-17.6	0.7	21.8
	MF	-16.2	2.9	25.8	-15.7	6.2	30.2
	FF	-15.1	5.2	30.8	-11.1	12.2	40.2

The monthly streamflow projections (Figure *75* and Table 52) from the CMIP6 GCM ensemble reveal a significant shift in water availability throughout the year. Under SSP 585, the most substantial projected increase in streamflow is for July, with a median increase of 13.46% in the far future. Other months also show notable changes, such as January which is projected to undergo an ensemble median increase of 12.38% under SSP 585 in the far future. In contrast, the most significant projected decrease is for February, which shows a median reduction of 7.48% in the far future under SSP 585 scenario, suggesting a drier period within the winter months. This uneven distribution indicates a future where streamflow is more concentrated in certain months, creating a more pronounced seasonal differences.

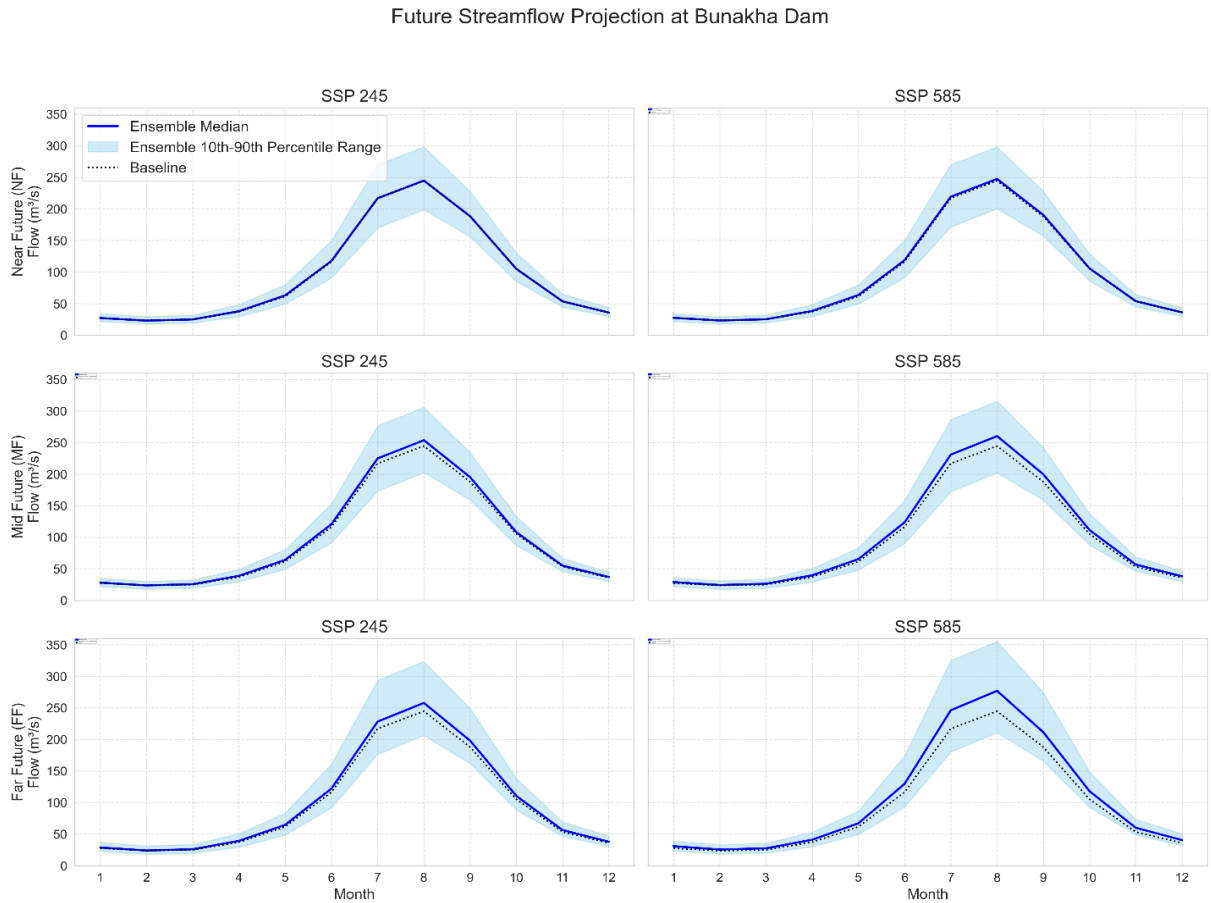


Figure 75: Projected monthly hydrograph at Bunakha dam under CMIP6 scenarios. The blue shade represents the uncertainty in projection by thirty GCM model.

Table 52: Projected changes (%) in streamflow in mid future (MF: 2040-2059) under different climate change scenarios

MF: 2040-2059	SSP 245			SSP 585		
	10th-percentile	Median	90th-percentile	10th-percentile	Median	90th-percentile
Jan	-19.9	2.8	27.7	-20.0	5.9	32.1
Feb	-24.5	0.1	26.1	-25.2	2.6	30.1
Mar	-22.0	3.1	30.0	-23.1	5.7	34.2
Apr	-20.6	4.8	32.2	-21.9	7.2	36.1
May	-20.0	4.4	30.9	-21.9	6.4	34.8
Jun	-21.5	3.7	31.1	-22.6	6.2	35.7
Jul	-20.2	3.7	27.5	-20.7	6.5	31.9
Aug	-17.2	3.8	24.9	-17.4	6.4	29.1
Sep	-15.3	4.0	24.7	-15.4	6.4	28.8
Oct	-17.1	2.8	26.3	-16.7	6.0	30.7
Nov	-14.1	3.3	24.6	-13.5	6.5	29.0
Dec	-16.5	3.2	25.4	-16.1	6.3	29.8

Uncertainties

It is important to consider the wide range of uncertainty associated with these projections. The uncertainty is highlighted by the 10th and 90th-percentile values from the CMIP6 GCM ensemble. For example, for the mid future under the SSP 585 scenario, the ensemble median projection of annual streamflow is an increment of 6.3%. However, the full range of projections extends from a potential decrease of -18.6% at the 10th-percentile to a substantial increase of 31.2% at the 90th-percentile. This widespread in the ensemble data underscores that while an increase in streamflow is the majority projection, the precise magnitude of this change is highly uncertain. At monthly scale, while the median values provide a likely future trajectory, the projections carry a wide range of uncertainty, mainly under SSP 585. For example, during the monsoon months (June to September) in the far future, the range of change can be as wide as 59.46% under SSP 245 and an even more significant 69.91% under SSP 585. This means that for a given month, while the median may project a strong increase, there is also a plausible outcome (represented by the 10th-percentile) of a notable decrease in streamflow. This broad range of possibilities is critical for planning, as it requires a resilient strategy that can manage both potential floods from a much wetter monsoon and the risk of lower water availability.

At monthly scale, streamflow projections show some parallels and differences with the findings of Zam et al. (2021) on the Wangchhu Basin. While in this study, ensemble median consistently projects an increase in streamflow across most months, Zam et al. (2021) projected potential reduction in months except March to July. They were limited to three CMIP5 regional climate models; ACCESS, CNRM-CM5, and MPI-ESM-LR to generate precipitation, temperature, and streamflow projections under RCP scenarios. They projected a decrease in both rainfall and streamflow, with a projected reduction of average annual streamflow up to 8.9% and 12.5% under RCP 4.5 and RCP 8.5, respectively. This highlights the uncertainty of studies arising from choice of climate models, emission scenarios, socio-economic pathways, hydrologic modeling parameters and methodologies, which can produce different results even for the same river basin. However, the broad spectrum of future projections (suggested by CMIP6 GCM ensemble 10th-percentile, median, and 90th-percentile projection) from this study address their projection as well. Incorporating the range of projection instead of ensemble median can guide for planning resilient strategy that can manage both potential higher and the risk of lower water availability.

Implications

Change in streamflow pattern necessitates the shift from historical/baseline to dynamic reservoir operating policies that can adapt to this change and optimize the operation. From a storage project perspective, the projected changes in streamflow might present an operational challenge. The substantial increase in streamflow during the monsoon season, particularly 13.46% rise in July (ensemble median in far future) under SSP 585, implies that reservoirs will fill much more rapidly. This requires careful management to balance the need for flood control, by releasing water during peak flows, with the imperative to store enough water to maintain generation and downstream supply during drier periods. Conversely, the projected decline in streamflow during the winter months, such as 2.7% decrease (SSP 245: MF: ensemble median in near future) in February under SSP 245, makes a storage reservoir's role a bit critical. The stored water is essential to compensate for the reduced natural flow and ensure a consistent energy supply when inflows are low.

The projected change in stream flow will impact the energy generation from the Bunakha dam and expected additional energy benefit from the downstream projects. Increased flow in the low flow season will add to the quantity and reliability of energy generation. However, all the increased flow may not contribute to positive benefit due to reservoir's physical (small live storage, about 10% of the annual runoff) and plant's hydraulic constraint.

In one hand, the storage capability of the Bunakha HPP can be one of the many strategies for adapting to climate change in the Wangchhu basin. On the other, the hydrologic extremes can increase challenges in operation and safety of the Project and the downstream projects. The basin is projected to have a higher flood, soil erosion, and sediment load, which will instead affect the active storage, safe operation, and maintenance of headworks and other structures.

Adaptive Reservoir Operation

Although climate change directly impacts water availability, its effects should be understood by exploring adaptive management strategies. This involves **developing flexible operation rules that can adjust to the changing climatic projections**. Rather than relying on static, historical guidelines, these new rules would incorporate climate projections to optimize water storage and release decisions. Such an approach is crucial for ensuring the long-term resilience of water infrastructure.

9.3.2.5 Sediment

Bhutan's rivers, originating from the Himalayas, carry a high sediment load, especially during the monsoon season. The soil loss estimation for Wangchhu river basin is observed to be 2122t /yr and 0.004 t/ha/yr (Gyeltshen et al., 2021). Based on the Updated DPR (Feb. 2026), hydrology section, the data available at Chhukha intake has been adopted for the Bunakha project. The average sediment load is calculated at 0.44 Mt/year, which is equivalent to 124 t/km^2. Figure 76 shows the monthly average sediment transport on Wangchhu at Chhukha. An estimate based on the regional equation developed for the Hindu Kush – Himalayan region indicates the sediment yield as high as 6.68 Mt/year.

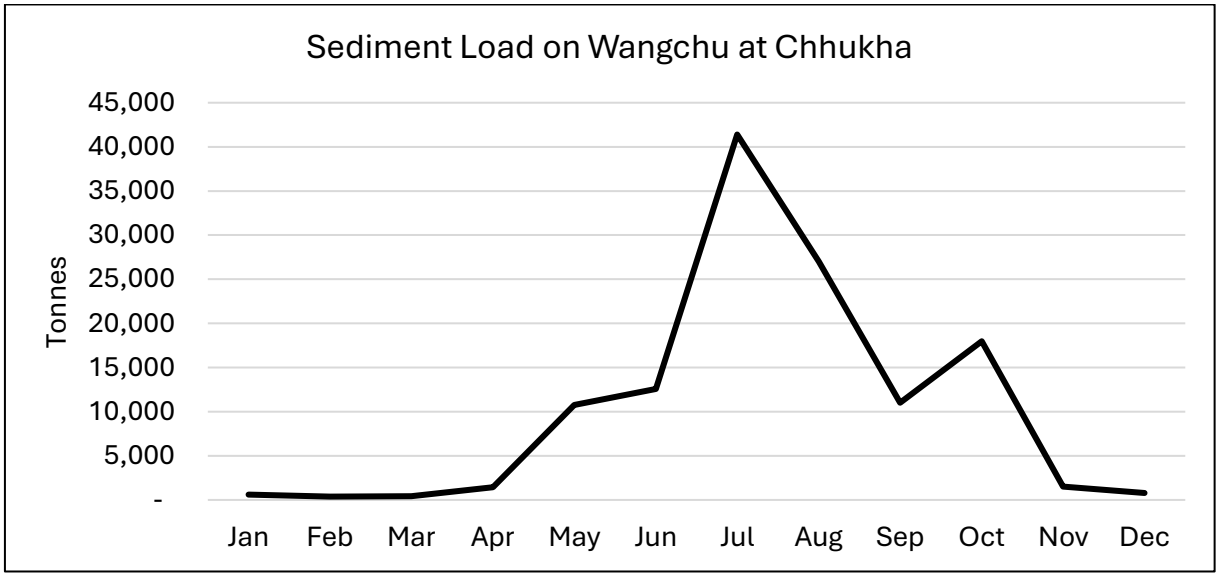


Figure 76: Average sediment transport on Wangchhu at Chhukha obtained from Hydrology report

The projected change in hydroclimatic variables like precipitation and stream flow will alter the sediment load at the Bunakha dam. **The increased hydroclimatic extremes can trigger events, such as landslides and debris flows transporting a massive amount of sediment**. A proper maintenance of the dam is needed through strategies like flushing, sluicing, and dredging, and even allocating a larger dead storage. Options like sloping intakes can be proposed considering future sediment load. The most prominent impact is the loss of storage capacity, which reduces the active storage leading to reduced hydropower output. Proper basin wide sediment management strategies should be developed by BHPL to ensure the reservoir's life. Watershed management, upstream sediment traps, bypass channel/tunnel, etc. are some of the preventive measures.

9.3.3 Glacial lake outburst flood (GLOF)

Glaciers and glacial lakes act as significant freshwater reservoirs and are the sources of several major rivers in Bhutan (F. Shrestha et al., 2023; Tariq et al., 2021). They play a crucial role in supporting communities downstream, particularly during the dry periods. However, increase in future temperature projections is likely to accelerate glacial melting, leading to the expansion of glacial lakes. This increases the risk of lake outbursts, which can result in severe downstream flooding and erosion. GLOFs often involve a cascade of different processes which can increase the spatial reach and destructive power of the event (Sattar et al., 2021).

Rinzin et al. (2021) concluded that the increasing glacier melt is the main driver of glacial lake expansion in Bhutan. The rapid melting poses a growing threat to both water security and flood management in the region (Namgay, 2023). The Lugye GLOF in 1994 and Lemthang GLOF in 2015 are the most devastating recorded so far. The details on 18 GLOF events in Bhutan are mentioned in Table 53.

Table 53: List of past GLOF events in the Bhutan Himalaya. Modified from (Rinzin et al., 2021) and (F. Shrestha et al., 2023)

No.	Name of the lake/glacier	Location	Year	Trigger of outburst	Volume (Million m^3)	Discharge (m^3/s)	Impact distance	Source
1	Jhomolhari south	27.789, 89.267	Before 1966	Glacier advance/ avalanche				Komori et al. (2012)
2	Pa-gl-47 (ICIMOD, 2012)	27.820, 89.346	1966−1974	Glacier advance/ avalanche				
3	Upper Chokham Tsho	27.836, 89.370	Before 1966	Glacier advance/ avalanche			7 km	
4	Simdong goi Tsho	28.217, 89.811	Before 1966	Unknown			13 km	
5	Unknown	28.035, 89.894	Before 1966	Glacier advance/ avalanche				
6	Any glaciers in Lunana	NA	1960s	Unknown				

No.	Name of the lake/glacier	Location	Year	Trigger of outburst	Volume (Million m^3)	Discharge (m^3/s)	Impact distance	Source
7	Tshojo glacier	28.055, 90.146	29th Apr 2009	Ice deformation	0.5			
8	Poge Tsho	28.333, 90.674	Before 1966	Unknown				
9	Upper Jiejiu Tsho	28.273, 90.713	Before 1966	Glacier advance/ avalanche				
10	Upper Shegong Tsho	28.304, 90.741	Before 1966	Glacier advance/ avalanche			15 km	
11	Cuolong glacier	28.070, 90.610	1955-1966	Glacier advance/ avalanche			28 km	
12	Tarikha glacier	28.028, 90.673	Before 1956	Unknown				
13	Chubda Tsho	28.020, 90.705	Before 1956	Ice deformation			9 km	
14	Gangri Tsho III	27.900, 90.807	1998	Glacier advance/ avalanche				
15	Lemthang Tsho	89.581, 28.068	2015	Upstream GLOF	0.37	1562	30 km	Gurung et al. (2017)
16	Lugge Tsho	28.092, 90.299	29th Oct 1994	Landslide	18	2500		Ives et al. (2010)
17	Tarina Tsho	28.104, 89.899	1957	Glacier advance/ avalanche			75 km	Veh et al. (2022)
18	Subsidiary lake II of Thorthomi Tsho	90.274, 28.105	20 Jun 2019	Glacier advance/ avalanche				NCHM (2019)

In Bhutan, Rinzin et al. (2021) identified 31 lakes with a very-high and 34 with high GLOF hazard levels. These very high to high GLOF hazard lakes were primarily located in the Phochu, Kurichu, Drangmechu, and Mochu basins. Details of glaciers and lakes in Wangchhu basin are provided in the Hydrology chapter of the DPR (2025), considering ICIMOD and NCHM report. According to Rinzin et al. (2021), Wohney Tsho and two nearby glacial lakes in Paa Chhu subbasin falls in very-high and high hazard GLOF risk (Table 54). These lakes are at ~100 km distance from the proposed dam site of BHPP (Figure 77). Analyzing the severity of impact from past GLOF events (Table 53), the possible volume and discharge from three lakes with ~0.2 km^2 area is likely to impact upstream more than the region near dam site.

Table 54: Potential lakes with high hazard GLOF risks in Wangchhu basin, upstream of Bunakha dam

No.	Long	Lat	Elevation (m a.s.l)	Area 2020 (km^2)	Hazard level (Rinzin et al. 2021)	Distance from Bunakha Dam
Wohney Tsho	89.409	27.687	4787.2	0.181	Very High	97.2
GL-II	89.313	27.800	4380.5	0.056	High	101.2
GL-III	89.350	27.804	4343.4	0.155	High	100.05

It can therefore be concluded with confidence that the **risk of an upstream GLOF event adversely impacting the Bunakha Dam is insignificant** as the distance of the dam from the dangerous lakes is about 100 km or more. The Spillways are designed to pass the Probable Maximum Flood value of 9,224 m^3/s (DPR 2026) which is significantly higher than any peak discharge should an upstream GLOF event were to happen.

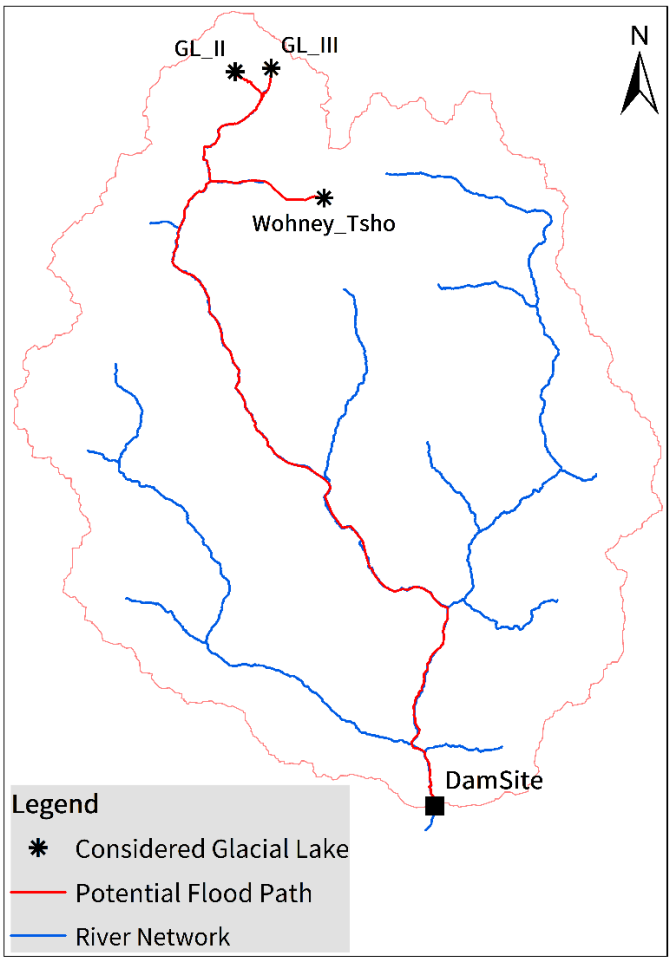


Figure 77: Location of three glacial lakes with high GLOF hazard level identified by (Rinzin et al., 2021). Red line denotes the potential path of flood up to Bunakha dam.

9.3.4 Landslide dam outburst flood (LDOF)

A landslide dam outburst flood (LDOF) occurs when a landslide blocks a river, creating a temporary lake, and the dam subsequently fails, releasing a large volume of water downstream. These dams are often created by initial landslides, triggered by heavy rainfall, earthquakes, or other geological events, and obstruct rivers or streams, creating temporary dams. The potential

energy buildup behind the dam destabilizes the landslide material. This can be highly destructive due to the rapid and forceful release of water and debris.

On September 10, 2003, a significant rock avalanche created a landslide dam on the Tsati Chhu, a tributary of the Kuri Chhu River, Eastern Bhutan. The rock avalanche was accompanied by an intense wind blast that caused substantial damage to the heavily forested valley slopes. On July 10, 2004, after reported smaller failures of the saturated downstream face due to prolonged intense rainfall, the dam was released by catastrophic collapse of the landslide (A. B. Shrestha, 2008). It released a flood wave with a peak discharge of 5,900 m^3/s at the Kurichhu Hydropower Plant 35 km downstream (Dunning et al., 2006). Due to the proper monitoring and the timely warning, the powerplant was able to take protective measures, significantly reducing damage and potential loss (A. B. Shrestha, 2008).

A careful assessment of potential landslide areas in the vicinity of Bunakha dam could help to take precautionary actions to mitigate such hazards. The DPR Team undertook a detailed walk over survey of landslides along the reservoir rim of the BHPP from 29 August to 1 September 2025 to evaluate their extent, activity, and potential impact on project infrastructure and surrounding communities. The study combined walk-over surveys, field mapping, verifying remote sensing report (TRE Altamira), and hazard–risk assessments to characterize 20 identified landslides and 5 terrain instability zones identified by TRE Altamira. The assessment concluded that the majority of slides are manageable through monitoring and minor stabilization, however, a small number of very high and high priority landslides represent significant risks to the BHPP (Updated DPR, February 2026) - see also Chapter 7.1.3.1 of the ESIA report.

Given the increasing frequency and intensity of extreme rainfall events in the Himalayas, evaluation of potential landslide dam formation upstream would provide new insights on safe operational strategy. Beyond the immediate Project site, a critical consideration is the potential for cascading impacts on existing and planned downstream hydropower projects within the Wangchhu basin, such as the Chhukha and Tala Hydropower Plants. An LDOF from an upstream event, or even a failure of the new dam itself due to an extreme LDOF, could unleash a devastating flood wave capable of overtopping, damaging, or even compromising the structural integrity of these downstream facilities. Therefore, the Project's risk mitigation strategy must extend to a basin-wide perspective, assessing the vulnerability of all downstream infrastructure, and establishing a unified early warning and emergency response protocol to minimize sequential failures and ensure collective safety and operational continuity.

9.4 Climate Change Risk Management Plan

A management plant to tackle the risks of climate change *on* the Project, including adaptation measures is prepared to inform the design and the operational procedures. The Climate Change Risk Management Plan (CCR MP) for the Bunakha HPP is shown in Table 55. It focuses on drivers of five key climate risks, described in the following sub-sections.

9.4.1 Changes in streamflows and energy generation

Projected warming temperatures and increasing precipitation with wetter summers and drier winters will lead to more variable streamflows impacting energy generation. However, based on the assessment of 30 global model projections available, projected changes in precipitation are highly uncertain, leading to uncertainty in future streamflows.

Reservoir simulation considering future changes in streamflows were assessed. The reservoir live storage capacity is a small percentage (12%) of the wet season flows; hence the reservoir is filled to the maximum level at the end of each wet season which will be available as regulated flows in the dry season. The projected changes in streamflows were assessed to have low impacts on energy generation. Hence, minimum impact is foreseen.

The recommended risk mitigation or adaptation measure is to implement an adaptive reservoir operation policy that allows flexible management in response to a more variable streamflow regime. BHPL will be responsible for managing the reservoir operation to adapt to likely changes in the streamflows (variability) due to future climate change.

9.4.2 Changes in floods (dam safety)

Future extreme precipitation (e.g. maximum 1-day and 5-day rainfall) (Table 50) is projected to increase leading to higher river flows. As a large dam, the Project is designed for Probable Maximum Flood (PMF) estimated as 8,180 m3/s compared to a 1000-year flood of 3,606 m3/s and checked with a combination of PMF and Glacial Lake Outburst Flood (GLOF). The check flood is also applicable for the powerhouse structures. The requirements are generally more stringent than the international best practice and thus the risk assessment is categorized as Low.

The recommended risk mitigation or adaptation measure is to design the spillways to pass the PMF and check for a n-1 (one gate mal functioning) scenario. The design engineers are responsible for this action, accordingly the Bunakha HPP dam is designed to safely pass the PMF, and the flood conveyance is checked for a n-1 (one gate mal function) scenario.

9.4.3 Impacts on GLOFs (dam safety)

Warming temperatures and higher extreme precipitation can lead to glacial lake expansion and thereby increase the chances of GLOFs. Review of past GLOF impacts (Table 53) show that the maximum distance of impacts ranges from 7 km to 75 km. Three glacial lakes of surface area ranging from 0.056 km2 to 0.81 km2 within the Bunakha HPP catchment area are categorized as high hazard GLOFs (Table 54). These are all around 100 km upstream of the dam site, hence their potential impacts are assessed to be low in comparison to the PMF design flood considered.

The recommended risk mitigation or adaptation measure is to regularly monitor the upstream glacial lakes. Mitigation measures such as lowering upstream lakes through siphoning and other measures can be implemented, if required. Currently, the upstream lakes are considered to have very low risks. The project operation and the national disaster risk management agencies will be responsible for adopting this adaptation measure.

9.4.4 Landslides and LDOFs (dam safety)

Extreme, high intensity precipitation and cloud bursts can lead to slope failures and landslides. Such landslides can block rivers which can eventually burst leading to LDOFs. Associated risks at Bunakha can be mitigated by a careful assessment of potential landslide areas in the vicinity of the dam; this assessment can support the development of precautionary actions to mitigate the risks.

In that sense, the DPR Team undertook a detailed walk over survey of landslides along the reservoir rim of the Bunakha HPP from 29 August to 1 September 2025 to evaluate their extent, activity, and potential impact on project infrastructure and surrounding communities. The

assessment concluded that most slides are manageable through monitoring and minor stabilization, however, a small number of very high and high priority landslides represent significant risks to the Bunakha HPP (Updated DPR, February 2026).

Proper monitoring and timely warning are recommended, significantly reducing risks for damages. In addition, the Project's risk mitigation strategy must extend to a basin-wide perspective, assessing the vulnerability of all downstream infrastructure, and establishing a unified early warning and emergency response protocol to minimize sequential failures and ensure the collective safety and operational continuity. National Disaster Risk Management Agencies would be best placed to carry this task.

9.4.5 Sediment load

The projected change in hydroclimatic variables like precipitation and stream flow will alter the sediment load at the Bunakha dam. The increased hydroclimatic extremes can trigger events, such as landslides and debris flows transporting a higher amount of sediment.

The risk mitigation or adaptation measure adopted by the Design Team is the provision of a bottom outlet in the dam which can be used to flush sediments which will help mitigate impacts of higher sediment loads, such as loss of storage. In addition, a mid-level outlet is also proposed in the design which can be used for sediment flushing to mitigate any risks of higher sediment load.

During the operation phase, adequate maintenance of the dam is recommended through strategies like flushing, sluicing, and dredging. Basin wide Sediment management strategies are recommended to ensure the reservoir’s life. Watershed management, upstream sediment traps, bypass channel/tunnel, etc. are some of the recommended preventive measures. The dam operator and the national agencies responsible for watershed management will be responsible for adopting these adaptation measures.

Table 55: Climate Risk Assessment and Management Plan for the Bunakha HPP

Drivers of Climate Risks	Description	Assessment	Comment	Risk Mitigation/Adaptation Measures
Changes in Streamflows and energy generation	Projected warming temperatures (Table 49) and increasing precipitation with wetter summers and drier winters (Table 48) will lead to more variable streamflows (Table 51 and Table 52) impacting energy generation. However, based on the assessment of 30 global model projections available, projected changes in precipitation are highly uncertain, leading to uncertainty in future streamflows.	Low risk	Reservoir simulation considering future changes in streamflows were assessed. The reservoir live storage capacity is a small percentage (12%) of the wet season flows; hence the reservoir is filled to the maximum level at the end of each wet season which will be available as regulated flows in the dry season. Hence, minimum impact is foreseen.	Bunakha HPP is a reservoir project, hence changes in the streamflows can be managed through adaptative reservoir operation. An adaptive reservoir operation policy (flexible operation) is recommended to adapt to a more variable streamflow regime.
Changes in Floods (Dam Safety)	Future extreme precipitation (e.g. maximum 1-day and 5-day rainfall) (Table 50) is projected to increase leading to higher river flows.	Low risk	As a large dam, the Project is designed for Probable Maximum Flood (PMF) estimate as 8,180 m^3/s compared to a 1000-yr flood of 3,606 m^3/s and check with a combination of PMF and Glacial Lake Outburst Flood (GLOF). The check flood is also applicable for powerhouse structures. The requirements are generally more stringent than the international best practice and thus the risk assessment is categorized as Low.	Design of the spillways to pass the PMF and checking for a n-1 (one gate mal functioning) scenario is recommended. The Design is carried out accordingly.
Impacts on GLOFs (Dam Safety)	Warming temperatures and higher extreme precipitation can lead to glacial lake	Low risk	Review of past GLOF impacts (Table 53) show that the maximum distance of impacts ranges from 7	Regular monitoring of the upstream glacial lakes is recommended. Mitigation measures such as

Drivers of Climate Risks	Description	Assessment	Comment	Risk Mitigation/Adaptation Measures
	expansion and thereby increase the chances of GLOFs.		km to 75 km. Three glacial lakes with surface areas ranging from 0.056 km^2 to 0.81 km^2 within the Bunakha HPP catchment area are categorized as high hazard GLOFs (Table 54). These are all around 100 km upstream of the dam site, hence their potential impacts are assessed to be low in comparison to the PMF design flood considered.	lowering of upstream lakes through siphoning and other measures can be implemented if required. Currently, the upstream lakes are considered of very low risk.

Drivers of Climate Risks	Description	Assessment	Comment	Risk Mitigation/Adaptation Measures
Landslides and LDOFs (Dam Safety)	Extreme, high intensity precipitation and cloud bursts can lead to slope failures and landslides. Such landslides can block rivers which can eventually burst leading to LDOFs	Medium risk	The Design Team undertook a detailed walk over survey of landslides along the reservoir rim of the Bunakha HPP from 29 August to 1 September 2025 to evaluate their extent, activity, and potential impact on project infrastructure and surrounding communities. The assessment concluded that most slides are manageable through monitoring and minor stabilization, but that a small number of very high and high priority landslides represent significant risks to the Bunakha HPP (Section 6.9, DPR 2026).	A careful assessment of potential landslide areas in the vicinity of Bunakha dam could help to take precautionary actions to mitigate such hazards (already undertaken - see DPR). Proper monitoring and timely warning is recommended to take protective measures, significantly reducing damage and potential loss. In addition, the Project's risk mitigation strategy must extend to a basin-wide perspective, assessing the vulnerability of all downstream infrastructure, and establishing a unified early warning and emergency response protocol to minimize sequential failures and ensure the collective safety and operational continuity. Bhutan's Disaster Risk Management Agencies would be best placed to carry this task.
Sediment Load	The projected change in hydroclimatic variables like precipitation and stream flow will alter the sediment load at the Bunakha dam. The increased hydroclimatic extremes can trigger events, such as landslides and debris flows transporting a higher	Medium risk	The dam design includes a bottom outlet which can be used to flush sediments which will help mitigate impacts of higher sediment loads, such as loss of storage. In addition, a mid-level outlet is also proposed in the design which can be used for sediment flushing to mitigate any	A proper maintenance of the dam is recommended through strategies like flushing, sluicing, and dredging, and even allocating a larger dead storage. Basin wide Sediment management strategies are recommended to ensure the reservoir's life. Watershed management, upstream sediment

Drivers of Climate Risks	Description	Assessment	Comment	Risk Mitigation/Adaptation Measures
	amount of sediment.		risks of higher sediment load.	traps, bypass channel/tunnel, etc. are some of the recommended preventive measures.

10 Environmental Impact Assessment

Potential impacts on the environment are assessed throughout the various Project phases (defined below). The assessment is based on the current available information and understanding of the Project, some of which will have to be updated and/or subject to change at a later stage (i.e. during the detailed design phase, appointment of the Contractor, etc.).

Impacts are expected in the following Project phases:

- Pre-construction phase: this one-year phase includes land acquisition, construction of the Project roads and bridge, utilities setup (power, water, telecommunications), contractor mobilization, setting up of camps and offices, construction of batching & crushing plants, construction of workshop and maintenance facilities, construction of the storage yard, setting up of the explosives magazine and the RCC lab, and performing additional surveys and investigations that may be required.
- Construction phase: river diversion, infrastructure works, E&M and H&M works, TL works, dam and powerhouse foundation excavation, dam concreting, construction of plunge pool and counter barrage, diversion tunnel plugging,
- Operation Phase: operation of the dam, water flow management, turbine operation, monitoring of generated energy, safety and emergency procedures, e-flow management, sediment management
- Decommissioning Phase: re-assessing the technical, economic, environmental and social impacts; prepare a decommissioning plan; obtain necessary approvals for decommissioning; perform related stakeholder engagement; controlled water release; sediment management; removal of infrastructure (partial or full); restoration works; safety and waste management.

Decommissioning of the Project is not foreseen within the current planning horizon, and no decision has been made regarding the eventual retirement of the hydropower facilities. In line with Bhutanese environmental regulations and the requirements of ADB's Safeguard Policy Statement (2009), a detailed assessment of social impacts and associated mitigation measures shall be prepared at the time when decommissioning is formally considered. Such an assessment shall reflect the regulatory framework, technical options, and community context prevailing at that future stage.

Given the long operational lifespan of hydropower infrastructure, it is neither feasible nor meaningful to predict specific decommissioning-related environmental impacts at this stage. However, the Project shall commit to ensuring that any future decommissioning activities will follow national legislation, obtain all required clearances, and be guided by good international industry practice, including the preparation of a Decommissioning Plan and associated environmental safeguards instruments.

In view of the above, the impact assessment follows the methodology described earlier consisting of three steps:

- Step 1: Distinguish positive and negative impacts
- Step 2: Dismiss non-significant impacts
- Step 3: Multi-criteria analysis for significant impacts pre- and post-mitigation:
  - Step 3(a): During pre-construction
  - Step 3(b): During construction
  - Step 3(c): During operation

The multi-criteria analysis is based on the formula and matrix shown below:

Magnitude vs Sensitivity = Significance

SIGNIFICANCE		**Magnitude of the impact**			
		Very high	*High*	*Medium*	*Low*
Sensitivity of the receptor	*Low*	High	Medium	Low	Low
	Medium	High	High	Medium	Low
	High	Very high	High	High	Medium
	Very high	Very high	Very high	High	High

The sensitivity of the receptors has been classified earlier in this report (Chapter 07); the magnitude is classified below for each impact expected, and the respective significance based on these two criteria as well. This exercise is done pre- and post-mitigation.

The main objective of the mitigation measures is to reduce impacts to “low”. For those impacts whose significance post-mitigation remains medium, high or very high (“residual impacts”), compensation or off-set measures are defined whenever technically and financially feasible.

Cumulative impacts are separately assessed.

10.1 Step 1: Distinguish Positive and Negative Impacts

10.1.1 Positive impacts on the physical environment

While the pre-construction, construction and decommissioning phases of the Bunakha HPP are expected to generate adverse impacts, the operational phase is expected to yield several long-term positive impacts on the physical environment at both regional and micro-environmental levels that extend far beyond the immediate Project footprint.

By displacing winter fossil-fuel imports, it directly reduces regional air pollution and GHG emissions. Through its regulated flow regime, it transforms the Wangchhu River from a seasonal system into one with dry-season flows and attenuated floods. The mandatory CAT Plan and infrastructure upgrades leave the watershed and local topography in a physically improved condition, with engineered stability that reduces erosion and landslide risks. When combined with the project's contribution to Bhutan's energy security, these environmental benefits position the Bunakha HPP as a sustainable, climate-positive development.

A summary of the expected positive impacts of the Project on the physical environment is provided in Table 56. The following sections describe these expected positive impacts in further detail.

Table 56: Summary of the expected positive impacts of the Bunakha HPP on the physical environment

Environmental aspect	Long-term positive impact	Description	Reference
Atmosphere and Climate	Climate change mitigation and displacement of	Displacement of winter fossil-fuel imports; offsetting 572,352 tCO_2e/year; prevention of regional	Chapter 9.1 of the ESIA Report

Environmental aspect	Long-term positive impact	Description	Reference
	winter fossil-fuel imports	thermal plant emissions (SO_2, NOx, PM).	
Hydrology	Hydrological flow regulation and dry-season augmentation	Augmentation of lean-season flows; maintenance of a permanent wetted perimeter via a E-flow; boosts downstream winter generation.	Section 9.1.2 (Table 78) of the DPR (Feb. 2026 update)
		Attenuation of peak flood events (PMF: 9,224 m³/s routed); reduction of downstream kinetic energy, riverbank scour, and soil erosion.	
		Improved dry-season water availability for downstream users.	
		157.90 million m³ live storage providing inter-seasonal regulation; gross storage of 240.53 million m³ at FRL (EL 2006 m).	Section 7.4 (Table 64) of the DPR (Feb. 2026 update)
Geomorphology	Watershed Stabilization via Catchment Area Treatment (CAT)	Physical stabilization of upstream degraded slopes via CAT Plan; reduction of natural landslide risks along the 17.25 km reservoir.	Section 6.8; Section 4.5 of the DPR (Feb. 2026 update)

Climate change mitigation and displacement of winter fossil-fuel imports

The BHPP delivers two major contributions to Bhutan's energy system and climate goals:

- Reduction in winter electricity imports: Bhutan's existing hydropower infrastructure is predominantly Run-of-River (RoR). Natural winter river flows drop so significantly that national generation reduces from a monsoon peak of ~3,600 MW down to just 650–700 MW. This physical deficit forces Bhutan to import up to 1,200 MW from the Indian regional grid to meet its domestic winter demand. Because the Indian grid is reliant on thermal coal[26], these winter imports carry a carbon and pollution footprint. Bunakha's winter storage generation will directly displace part of this need, physically preventing the transboundary emission of air pollutants (SO_2, NOx, $PM_{2.5}$).
- Greenhouse Gas (GHG) offsets: The GHG emissions reduction from the Bunakha HPP is estimated in the ESIA (Chapter 9.1) as of 572,352 tCO_2 equivalent annually considering an 6-hours peaking operation. This is equivalent to 15% of the estimate gross emission in 2015, and is in line to contribute to meeting the Carbon Neutral Policy targets of the Government (see Chapter 9.2).

Hydrological flow regulation and dry-season augmentation

[26] International Energy Agency (IEA): https://www.iea.org/countries/india?utm

The creation of the Bunakha reservoir (gross storage capacity: 240.53 million m³; live storage: 157.90 million m³) will alter the hydrology of the Wangchhu River, correcting the physical imbalance between monsoon and winter river flows:

- Dry-season flow augmentation: During the lean winter months (December to May), the reservoir will regulate and augment flows, ensuring a continuous, higher-volume discharge. This includes a mandatory Environmental Flow, which physically maintains the wett perimeter of the river, sustains aquatic habitats (supporting species like *Schizothorax richardsonii* and *Salmo trutta*), and boosts the winter generation capacity of downstream HPPs. Based on the Updated DPR (Feb. 2026) P90 cascade simulation, this flow augmentation translates to annual incremental generation benefits of 183 GWh at Chhukha HPP, 329 GWh at Tala HPP, and 120 GWh at the proposed Wangchhu HPP.
- Flood attenuation: During the monsoon season, the storage capacity of the reservoir will absorb and attenuate peak flood hydrographs. The 4-gate crest spillway is engineered to pass the DGPC -adopted Probable Maximum Flood (PMF) of 9,224 m³/s. This buffering effect reduces the kinetic energy of floodwaters, lowering the rates of downstream riverbank scour, soil erosion, and physical degradation of riverine habitats.

Watershed stabilization via Catchment Area Treatment (CAT)

While the project will submerge terrestrial habitats (an inundation area of 860.73 acres , including 829.32 ha of state reserved forest land and 31.38 acers of private land), the mandatory implementation of the Catchment Area Treatment (CAT) (Catchment Area 3,541 km^2) Plan will result in engineered physical improvements to the upstream watershed.

- Soil conservation: The installation of physical interventions such as check dams, contour bunds, and gully plugs within the degraded portions of the upstream catchment will arrest soil erosion. By addressing the baseline sediment load (estimated at 1.22 million m³/year), the CAT Plan reduces the natural sediment yield entering the Wangchhu River, thereby extending the reservoir's 158-year estimated half-life.
- Slope Stabilization: The bio-engineering and afforestation on vulnerable slopes above the reservoir will enhance soil matrix stability, reducing the risk of localized landslides. This complements the geotechnical stabilization measures planned for the reservoir rim, where the Rim Stability Study has identified and recommended treatment for potential landslide zones across the 17.25 km reservoir stretch.

A comprehensive project-level sediment assessment has been undertaken using sediment monitoring data (2008-2021), regional sediment yield analyses, bathymetric information from existing reservoirs, and reservoir sedimentation modelling. Sediment records collected within the Wangchhu basin indicate an average annual sediment transport of approximately 1.71 MT/year at the proposed project location, equivalent to about 483 t/km². The analysis also shows substantial year-to-year variability associated with hydrological conditions. Annual sediment loads ranged from approximately 0.22 MT in low-sediment years to more than 17 MT during extreme flood years, demonstrating the importance of rare but high-magnitude events in governing long-term sediment delivery.

Extensive vegetation cover helps limit soil erosion and sediment production compared with many other Himalayan river basins, although localized landslides, bank erosion, and extreme rainfall events remain important sources of sediment during the monsoon season.

Based on the adopted sediment transport estimates, the expected average sediment deposition rate is approximately 1.22 Mm^3/year, equivalent to about 0.34 mm/year of catchment sediment yield. The modelling suggests that reservoir sedimentation will occur gradually and is not expected to compromise the intended operational life of the Project. Empirical assessments based on regional Himalayan reservoir data indicate a reservoir half-life of approximately 158 years, demonstrating that the storage volume is expected to remain functional over the long term under anticipated sediment loading conditions.

As with any storage reservoir, sediment retention may reduce the quantity of sediment transported downstream. Over time, this may influence riverbed processes, channel adjustment, gravel bar formation, and aquatic habitat characteristics immediately downstream of the dam. The magnitude of these changes will depend on reservoir operation, sediment trapping efficiency, environmental flow releases, and the occurrence of natural flood events that continue to transport sediment through the river system. Potential downstream effects are expected to develop gradually and will be monitored throughout project operation.

To minimise potential impacts, BHPL shall prepare and implement a Basin Wide Sediment Management Plan. The Plan shall include regular sediment monitoring, periodic bathymetric surveys, tracking of reservoir sediment accumulation trends, and assessment of sediment management measures where required. Monitoring results will be used to support adaptive reservoir operation and to identify any emerging downstream sediment-related impacts.

10.1.2 Positive impacts on the biological environment

The Bunakha Hydropower Project is expected to generate certain indirect positive impacts on the biological environment, primarily through improved environmental management practices, and enhanced ecological knowledge.

Improved biodiversity monitoring and knowledge generation

The Project will establish and implement a long-term biodiversity monitoring program covering both aquatic and terrestrial ecosystems during construction and operation phases (see Chapter 14.3). Monitoring activities will include periodic surveys of mammals, birds, vegetation, and aquatic fauna, as well as assessment of habitat conditions.

The data generated through these monitoring programs will improve understanding of biodiversity patterns within the Wangchhu basin and support evidence-based conservation planning and adaptive management. This represents a direct positive impact, as it enhances scientific knowledge and strengthens long-term biodiversity management capacity at both Project and landscape levels.

Strengthening environmental awareness and compliance

The Project will promote environmental awareness among workers and nearby communities through structured training and engagement programs. These initiatives will enhance

understanding of biodiversity conservation principles and generally improve compliance with national environmental regulations.

Improved awareness and compliance are expected to reduce risks of illegal activities such as hunting and resource extraction, thereby indirectly supporting biodiversity conservation.

10.1.3 Enhancement measures for positive impacts

To further strengthen, amplify or extend the positive outcomes on the biological and physical environment, the Project may consider implementing enhancement measures.

To enhance hydrological / flow regulation benefits, the following can be considered:

- Coordinate multi-reservoir operations across the Wangchhu cascade for further smoothing of dry-season flows, improving both ecological stability and power generation.
- Planting native riparian vegetation along stabilized banks to reinforce the positive effects of regulated flows on erosion control and habitat quality.
- Periodic flushing or sluicing (as appropriate) to manage sediment accumulation and maintain channel morphology.

To enhance biodiversity monitoring and knowledge generation benefits, the following is suggested:

- Development of ecological corridors in coordination with afforestation programs
- Establishment of long-term funding mechanisms for biodiversity management plans and environmental awareness programs
- Collaboration with relevant agencies for integrated biodiversity monitoring at the watershed level
- Exploration of advanced aquatic management interventions, where feasible

To enhance environmental awareness benefits, the following could be implemented:

- Train local community members as “biodiversity para-monitors” to participate in surveys, improving local capacity and ownership of conservation outcomes.
- Collaborate with district schools to create student-led biodiversity clubs that use project monitoring data for learning and awareness.
- Publish short annual biodiversity bulletins summarizing key findings in accessible language for communities and local government.

10.2 Step 2: Dismiss Non-Significant Impacts

10.3 Step 3 (a): Multi Criteria Analysis - Impacts and Mitigation Measures During Pre-Construction

The one-year pre-construction phase includes land acquisition, construction of the Project roads and bridge, utilities setup (power, water, telecommunications), contractor mobilization, setting up of camps and offices, construction of batching & crushing plants, construction of workshop and maintenance facilities, construction of the storage yard, setting up of the explosives magazine and the RCC lab, and performing additional surveys and investigations that may be required.

10.3.1 Impacts on the physical environment

10.3.1.1 IESC#1 Air Quality

Impacts pre-mitigation

The transportation of construction materials, heavy machinery, and workers on the Thimphu-Phuentsholing Asian Highway 48 (AH48) will cause cumulative airshed degradation. Baseline traffic already shows exceedances of WHO guidelines for NO_2 and high $PM_{2.5}$ levels. Movement of Project traffic will exacerbate air quality.
Quarrying, crushing, and batching plants consolidated on the right bank near Chanachen Village will generate dust. During the dry season, atmospheric stagnation especially during night and morning hours causes pollutant buildup that impact human health and production of agricultural products; during the wet season, up-valley winds will carry dust and emissions through Chanachen and into Nayakha and Lobnekha Heritage Village.

Mitigation Measures:

Contractor will conduct preventive measures as follows:

- Enforce relocated footprints for Labour Camps 1 & 2 and Client Offices as strict "No-Go" constraints on private land in Bunakha village.
- Orient exhaust vents, aggregate dropping points, and material stockpiles at the Chanachen crusher site perpendicular to prevailing up-valley winds to prevent dust plumes from channeling into Nayakha and Lobnekha Heritage Village.
- All project machinery and transport vehicles must undergo compulsory, documented emissions testing every six months. Vehicles noncompliance to national emission standards must be immediately banned from the site.
- All trucks transporting aggregate, sand, or muck must be securely covered with tarpaulins.

Contractor will adopt following corrective measures:

- Maintain the continuous ambient air quality (PM_{10}, $PM_{2.5}$, NO_2, SO2 & O3) measurement established during the baseline survey at critical receptor points (e.g., ANSP- Tshimalakha, ANSP-4 Bunakha Lhakhang).
- Extensive water suppression must be used on all active quarry faces and internal haul roads, drawing water exclusively from the Wangchhu River, not from the Chanachen community drinking water spring (SW-10).

Summary Table

IESC #1: Air Quality
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	1	Mitigation measures must be adopted as per 13.5.8 Air quality and noise management plan,
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Irregular	2	

Ability to recover	Reversible	1	Reversible	1	13.5.10 Alternative fuel and energy supply plan
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		16		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

10.3.1.2 IESC#2 Noise

Impacts pre-mitigation

The siting of project facilities must account for acoustically pristine communities (e.g., Chanachen and Nayakha with baseline noise levels as low as 36–40 dBA) to prevent disproportionate impacts on quiet receptors.

Additional heavy vehicle traffic on AH48, particularly at night, threatens to exacerbate noise levels above the national night-time limit of 55 dBA, causing sleep disturbance for residents.

Quarrying, crushing, and batching plants near Chanachen Village will cause severe acoustic intrusion. The continuous, high-decibel noise from rock crushers, blasting at INRQ 3 (100m proximity), and heavy vehicle movements will exceed national night-time limit of 55 dBA will cause a severe, jarring disruption to this soundscape, leading to community distress.

Mitigation Measures:

Preventive:
Contractor will adopt preventive measures as follows;

- Acoustic Buffer Preservation: Co-locate the aggregate crushing unit, RCC/CVC batching plants, and Muck Disposal Site 3 (MD-3) strictly within the already designated Chanachen right-bank corridor.
- Prevent any infrastructure "creep" further north to safeguard the pristine 36-40 dBA acoustic baseline of Chanachen and Nayakha village.
- Night-Time restriction: To prevent exceedance of the 55 dBA night-time noise limit, heavy project logistics and bulk material haulage through sensitive settlement zones (like Bunakha and Chanachen) must be restricted to daytime hours (06:00 to 22:00).
- Acoustic Buffering and restrictions: To protect the pristine 36-40 dBA baseline of Chanachen, crushing, batching, and material loading operations must be strictly prohibited during night-time hours (22:00 to 06:00).

Contractor will adopt corrective measures as follows;

- Maintain the continuous ambient noise monitoring stations established during the baseline survey at critical receptor points (e.g., ANSP- Tshimalakha, ANSP-4 Bunakha Lhakhang).

IESC #2: Noise
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Mitigation measures must be adopted as per 13.5.8 Air quality and noise management plan
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		14		9	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

10.3.1.3 IESC#3 Water Quality

Impacts pre-mitigation

Temporary land leasing for material laydown areas, staging yards, and storage depots introduces risks of point-source contamination from drips of hydraulic fluid, diesel, or leaching of alkalinity from cement storage, which can alter the pristine heavy-metal baseline of the soil.
Vegetation removal strips the protective biological layer, leading to erosion during monsoon. Runoff from cleared areas will exacerbate turbidity in the Wangchhu River, which is already highly sensitive to runoff-induced sediment.
Quarrying and batching plants generate highly alkaline wastewater and present a high risk of hydrocarbon leaks. Any spills from these facilities below the farm road will wash directly into the Wangchhu River, violating its pristine "zero-tolerance" baseline.

Mitigation Measures:

Preventive:

- Any contractor-proposed storage or laydown areas must undergo spatial screening to guarantee they do not violate the mandatory 50-meter "No-Go Buffer Zones" around community drinking water springs (SW-05, SW-07, SW-09, and SW-10).
- In highly vulnerable zones like the Chanachen right bank, vegetation clearing must be immediately followed by the installation of structural erosion controls, including interceptor drains and gabion toe walls to prevent sediment washing into Wangchhu River.
- Batching plants must operate with a Zero Liquid Discharge (ZLD) goal. Concrete wash-water must pass through a pH neutralization unit before passing through multi-stage sedimentation pits. Treated water must be recycled; direct discharge into the Wangchhu River is prohibited.

- All fuel depots, lubricant stores, and chemical admixture areas at batching/crushing sites must be on impervious concrete flooring surrounded by bund walls capable of holding 110% of the largest tank's volume. API Oil/Water separators must be installed on drainage lines exiting workshop areas.
- Contractors must install and operate modular Water Treatment Plants (WTPs) that includes physical filtration and UV/chlorination disinfection to provide safe, potable water for all temporary labour camps, prohibiting reliance on raw community water sources.
- All camps must be equipped with engineered septic systems or package Sewage Treatment Plants (STPs) located at least 50 meters away from any natural watercourse or community spring.

Corrective:

- Implement real-time, automated water quality monitoring (specifically for pH, Turbidity, and Dissolved Oxygen) at SW-01 (Dam Upstream) and SW-02 (Dam Downstream) to immediately detect and rectify any contamination spikes.

IESC #3: Water Quality
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		14		9	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

10.3.1.4 IESC#4 Soil Quality

Impacts pre-mitigation

Temporary land leasing for material laydown areas, staging yards, and storage depots will cause severe soil compaction from heavy vehicle parking, destroying natural soil porosity (currently 36-46%), drastically reducing water infiltration rates and destroying the subsurface micro-biome.

Prolonged staging of vehicles and storage of materials introduces risks of point-source contamination from hydrocarbon drips or cement alkalinity, which can chemically alter the pristine neutral-to-acidic pH (4.65 - 6.94) and heavy-metal baseline.

Unmanaged vegetation clearing will result in the immediate loss of the highly fertile, biologically active topsoil layer (organic carbon >0.95%), which is critical for future site rehabilitation.

Mitigation Measures:

Preventive:

- Restrict temporary leasing for laydown areas and storage yards to identified fallow land patches or designated state forest lands, explicitly prohibiting the leasing of active agricultural terraces in Bunakha and Chanachen villages.
- Contractor should Implement a mandatory "Topsoil Management Protocol" for all leased land. The fertile top 300mm of organic soil must be stripped, stockpiled separately (away from drainage paths), bounded by silt fencing, and planted with fast-growing native grasses.
- Require all heavy machinery parked on leased private land to utilize drip trays. Any localized fuel or oil spills must be excavated and treated immediately.
- Contractor must ensure that all fuel depots, lubricant stores, and chemical admixture areas at batching/crushing sites must be on impervious concrete flooring surrounded by bund walls capable of holding 110% of the largest tank's volume.

Corrective:

- Contractor/BHPL must enforce strict handling protocols for concrete admixtures, fuels, and lubricants. Refueling of heavy machinery within 50 meters of the active river channel is prohibited.

IESC #4: Soil Quality
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Irreversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		14		9	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	Medium				
=					
SIGNIFICANCE	Medium		Low		

10.3.2 Impacts on the biological environment

The Bunakha Project Area of Influence (AoI) supports ecologically significant aquatic and terrestrial biodiversity under generally good environmental conditions. However, the presence of sensitive habitats and species of conservation importance indicates potential vulnerability to project-related impacts.

Key impact pathways include hydrological alterations affecting aquatic ecosystems and habitat disturbance or fragmentation affecting terrestrial biodiversity. These findings highlight the need for appropriate mitigation measures, including maintenance of environmental flows, protection of critical habitats, and preservation of ecological connectivity.

The established baseline provides a robust foundation for subsequent impact identification, significance evaluation, and development of mitigation and biodiversity management measures in accordance with ESIA requirements. These measures will be further detailed in the Biodiversity Management Plan and associated sub-plans to ensure compliance with applicable international standards and safeguard requirements.

The absence of widespread invasive species and limited herpetofauna sensitivity further support the conclusion that ecological impacts are expected to remain localized and manageable. The baseline assessment confirms that the project area constitutes predominantly Natural Habitat with moderate ecological sensitivity and no confirmed critical habitat within the immediate footprint.

An initial qualitative assessment of impacts on the biological environment has been made in the Working Draft ESIA.

10.3.2.1 IESC#7: Protected Areas, Critical Habitat and Ecological Connectivity

Impacts pre-mitigation

Project siting and design within Bhutan's biological corridor network introduce inherent risks to ecological connectivity. The planning of the reservoir extent, infrastructure footprint, and access routes may influence the continuity of forest habitats and wildlife movement pathways at the landscape level.

Mitigation Measures:

- Avoid high-sensitivity habitats during final siting and optimize project footprint
- Minimize alignment through ecologically sensitive areas and maintain vegetation buffers
- Integrate ecological connectivity considerations into design (avoid unnecessary fragmentation)
- Prepare Biodiversity Conservation and Wildlife Management Plan (BCWMP)

IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity
Impacts Pre-construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	2	

IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity Impacts Pre-construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Duration	Long term	3	Mid term	2	
Frequency	Occasional	2	Occasional	2	
Ability to recover	Partially reversible	2	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	Medium	2	Low	1	
Sum		12		10	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		High		

10.3.2.2 IESC#8: Terrestrial Habitats and Faunal Communities

Impacts pre-mitigation

Project activities will result in direct loss, fragmentation, and modification of terrestrial habitats within the AoI. Vegetation clearance, land take, and infrastructure development will reduce habitat availability and alter habitat structure, while construction-related disturbances may lead to temporary displacement and behavioural changes in fauna.

Habitat fragmentation and edge effects may influence species distribution and increase exposure to anthropogenic pressures. However, impacts are largely confined to the project footprint and adjacent areas, with limited implications at the broader landscape scale.

Although ecological recovery may occur through natural regeneration and restoration measures, permanent land-use change associated with reservoir formation and infrastructure will result in long-term modification of habitat conditions.

The impact is therefore assessed as long-term and partially reversible, with residual effects remaining at the project scale despite mitigation measures.

Project layout and infrastructure planning determine the extent of forest clearance and habitat fragmentation within the AoI, including areas supporting terrestrial fauna.

Based on the assessment of impact magnitude prior to mitigation, the Project's impacts on terrestrial habitats during the design and pre-construction phase are regional in extent, long-term in duration, and moderate in intensity, resulting in a High magnitude of impact. Considering the High sensitivity of the receptor, the impact significance is assessed as High.

Mitigation Measures:

- Avoid high-value habitat patches during final design and micro-siting
- Optimize project footprint to minimize vegetation clearance and fragmentation
- Clearly demarcate vegetation clearing boundaries prior to construction

IESC #8: Terrestrial Habitats and Faunal Communities Impacts Pre-construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	2	
Duration	Long term	3	Long term	2	
Frequency	Occasional	2	Occasional	2	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Probable	3	Probable	2	
Intensity	Medium	2	Medium	1	
Sum		15		11	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

With the implementation of mitigation measures, the magnitude of impact is reduced to Medium. However, considering the sensitivity of the receptor, the residual significance remains High.

10.3.2.3 IESC#9: Aquatic Ecology and Environmental Flow Regime

Impacts pre-mitigation

The project will alter flow regimes, sediment dynamics, and aquatic habitat characteristics within the Wangchhu River system. Key impact pathways include flow regulation, reservoir formation, sediment trapping, and changes in channel morphology.

Baseline studies indicate low fish diversity and limited evidence of active long-distance migration within the project stretch; therefore, impacts primarily affect habitat conditions and ecological processes rather than major migratory pathways.

Conversion of riverine (lotic) habitats to reservoir (lentic) conditions will modify habitat structure and influence aquatic community composition. Changes in environmental flow and sediment transport may also affect downstream ecological processes.

Although mitigation measures under the Fisheries Conservation and Management Plan (FCMP) will reduce impacts, permanent hydrological alteration cannot be fully mitigated. The impact is therefore long-term and partially irreversible, with high residual significance.

Hydrological design, including environmental flow provisions, will influence the extent of flow alteration and aquatic habitat conditions.

Based on the assessment of impact magnitude prior to mitigation, impacts are regional and long-term, resulting in a high magnitude of impact. Considering the Very High sensitivity of aquatic receptors, the significance is assessed as Very High.

Mitigation Measures:

- Integrate environmental flow (E-flow) requirements into design
- Avoid sensitive in-stream areas during planning

IESC #9: Aquatic Ecology and Environmental Flow Regime Impacts Pre-construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	2	
Duration	Long term	3	Mid term	2	
Frequency	Occasional	2	Occasional	2	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Probable	3	Possible	2	
Intensity	Medium	2	Low	1	
Sum		15		11	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		High		

Mitigation measures reduce uncertainty in impact extent; however, the magnitude remains High due to inherent hydrological modification, and significance remains High.

10.4 Step 3 (b): Multi Criteria Analysis - Impacts and Mitigation Measures During Construction

The 5-year construction phase consists of the main activities river diversion, infrastructure works, E&M and H&M works, TL works, dam and powerhouse foundation excavation, dam concreting, construction of plunge pool and counter barrage, and diversion tunnel plugging.

10.4.1 Impacts on the physical environment

10.4.1.1 IESC#1 Air Quality

Impacts pre-mitigation

Quarry blasting (INRQ-3, 100m from Chanachen) and dam foundation blasting will eject pulverized rock and dust. Prevailing up-valley winds will transport dust plumes northwards, directly impacting Chanachen, Bunakha, and downwind receptors of Nayakha and Lobnekha Heritage Village.

The transportation of 0.43 million m³ of excavated material from the powerhouse complex to disposal sites (MD-2, MD-4) will involve high-frequency heavy truck movements, significantly elevating local dust and NOx emissions along internal haul routes.

The project's heavy construction fleet on AH48 will exacerbate the already stressed airshed, which currently shows exceedances of WHO guidelines for NO_2 and high $PM_{2.5}$ levels.

Mitigation Measures:

Preventive:

- Muck Transport Protocol: Contractor must ensure that all haul trucks traveling to muck disposal sites must be securely covered with tarpaulins. Mandatory wheel-washing facilities must be operated at the powerhouse exit.
- Strict Emission Controls: All project machinery and transport vehicles must undergo mandatory; documented emissions testing every six months and maintain regular servicing card. Vehicles failing to meet national emission standards must be immediately banned from the site.
- Dust Prevention: All trucks transporting aggregate, sand, or muck must be securely covered with tarpaulins. Wheel-washing facilities must be installed at the exits of quarry and batching plants.
- Strict Scheduling and Community Warning: Conduct blasting operation as per Blasting Operation Plan.

Corrective:

- Continuous Monitoring: Maintain continuous ambient air quality (PM_{10}, $PM_{2.5}$, NO_2, SO2 & O3) monitoring stations at critical receptor points (e.g., ANSP- Tshimalakha, ANSP-4 Bunakha Lhakhang).
- Water Sourcing for Dust Suppression: Use extensive water suppression on all active quarry faces, internal haul roads, and the powerhouse exit, drawing water exclusively from the Wangchhu River.

IESC #1: Air Quality
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	1	
Duration	Medium term	2	Medium term	2	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Unlikely	1	
Intensity	High	3	Medium	2	
Sum		17		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

10.4.1.2 IESC #2 Noise

Impacts pre-mitigation

Blasting for the dam foundation (670m from Chanachen) and quarry (100m from Chanachen) will cause acoustic shock and vibration. The sudden shockwaves and air overpressure, amplified by the river valley, will cause severe startle effects and intense disturbance to local residents with a pristine acoustic baseline (36-40 dBA).

Tunnel drilling, blasting, and continuous heavy equipment operations at the river level will channel noise upward through the gorge, potentially disrupting nearby Chanachen.

Additional heavy vehicle traffic on AH48, particularly at night, threatens to push noise levels beyond the national night-time limit of 55 dBA, causing sleep disturbance for residents.

Mitigation Measures:

Preventive:

- Strict Scheduling and Community Warning: Restrict blasting to a fixed daytime window (e.g., 12:00 PM to 13:00 PM). A mandatory siren warning system must be implemented, and local leaders of Chanachen and Bunakha must be notified at least 24–48 hours in advance of major dam foundation or quarry blasts.
- Night-Time restriction: Heavy project logistics and bulk material haulage through sensitive settlement zones (like Bunakha and Chanachen) must be restricted to daytime hours (06:00 to 22:00).

Corrective:

- Real-Time Vibration Monitoring: Install continuous seismographs/vibration monitors at Bunakha Lhakhang, the base of Lamche Bja, and the nearest houses in Chanachen.
- Continuous Monitoring: Maintain continuous noise monitoring stations at critical receptor points (e.g., ANSP- Tshimalakha, ANSP-4 Bunakha Lhakhang).

IESC #2: Noise
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Medium term	2	Medium term	2	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Low	1	
Sum		15		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

Compensatory:

- Conduct a comprehensive structural condition (dilapidation) survey of every residential, commercial, and religious structure within Chanachen and Bunakha villages, as well as the Lamche Bja cliff face, to establish a baseline for damage claims.

10.4.1.3 IESC #3 Water Quality

Impacts pre-mitigation

River flow alteration: The diversion tunnels will route the full 25-year flood discharge (1,822 m³/s), leaving approximately 1 km of river channel completely dewatered.

Sedimentation and Turbidity: Massive earthworks, including 4.30 million m³ of excavation for the dam complex, will drastically spike Total Suspended Solids (TSS), smothering benthic habitats and degrading water quality. Exposed excavation faces will remain vulnerable to erosion.

Chemical Contamination: Accidental spills of alkaline materials (cement, fly ash) or hydrocarbon leaks from heavy machinery operating in the riverbed will violate the "zero-tolerance" baseline for industrial pollutants.

Runoff from deep excavation, alkaline wastewater from concreting, and effluent from the powerhouse located at the river's edge, effluent from the access tunnel (often contains high suspended solids and traces of explosive residues) pose a direct threat to the "zero-tolerance" chemical baseline of the Wangchhu River.

Muck disposal sites (MD-1, MD-2, MD-4) pose risks of erosion and sedimentation of downstream watercourses and leachate generation affecting water quality.

Mitigation Measures:

Preventive:

- Hazardous Materials Protocol: Enforce strict handling protocols for concrete admixtures, fuels, and lubricants by contractor/BHPL. Refueling of heavy machinery within 50 meters of the active river channel is prohibited.
- Engineered Water Treatment: Install multi-chamber sedimentation basins equipped with API oil/water separators to treat tunnel effluent. All concrete wash-water must pass through a pH neutralization unit before discharge.
- Strict Footprint Containment: Earthworks and vegetation clearing must be strictly confined to the demarcated powerhouse footprint. Encroachment or unauthorized dumping of muck into the river channel is prohibited.
- Erosion and Sediment Control Plan (ESCP): Prior to any ground disturbance, a site-specific ESCP must be approved, detailing slope stabilization sequencing, diversion ditches, and sediment basins for all disturbed areas.

Corrective:

- Regular Water Quality Monitoring: Implement real-time, automated water quality monitoring (specifically for pH, Turbidity, and Dissolved Oxygen) at SW-01 (Dam Upstream) and SW-02 (Dam Downstream) to immediately detect and rectify any contamination spikes.
- In-Stream Sediment Control: Deploy physical sediment barriers, such as turbidity curtains and settling basins within the diversion channels, to capture suspended solids before water is returned to the main river course.
- Establish Sedimentation Ponds: Prior to any muck disposal, properly designed sedimentation ponds shall be constructed at the toe of each primary disposal site (MD-1, MD-2, MD-4) to intercept sediment-laden runoff.

IESC #3: Water Quality Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Medium term	2	Medium term	2	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	

IESC #3: Water Quality
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		15		10	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Environmental Flow (E-Flow) Maintenance: Maintain a continuous, ecologically calculated minimum environmental flow through the diversion tunnels at all times.

10.4.1.4 IESC #4 Soil Quality

Impacts pre-mitigation:

- Muck disposal sites (MD-1, MD-2, and MD-4) pose significant risks of slope instability, landslides, and erosion due to moderate slopes located above access roads in MD-2, MD-4 and MD-1 above reservoir area.
- Chemical contamination risks from hydrocarbon leaks from heavy machinery fleets operating in the riverbed and alkaline spills from cement and fly ash used in RCC placement.
- Soil contamination from hazardous wastes and spills during powerhouse and transmission line construction.
- Soil erosion from vegetation clearing for the dam, powerhouse, transmission line corridor, and tower foundations.

Mitigation Measures:

Preventive:

- Refer to Detailed Muck Disposal Plan: Adhere to the approved Muck Disposal Plan detailing site-specific engineering controls, including gabion toe walls, phased dumping and compaction, stormwater management, and leachate management.
- Hazardous Materials Protocol: Enforce strict handling protocols for concrete admixtures, fuels, and lubricants. Secondary containment shall be provided for all fuel storage tanks.
- Strict Footprint Containment: Earthworks and vegetation clearing must be strictly confined to the demarcated footprints.
- Topsoil conservation: Strip and stockpile topsoil from disposal site footprints and other construction areas for later use in rehabilitation.

Corrective:

- Implement Progressive Rehabilitation: Carry out dumping in a phased manner to allow for progressive rehabilitation of completed slopes. Re-vegetate all completed surfaces with locally native plant species.
- Geotechnical monitoring: Conduct regular inspection of slope stability, toe walls, and drainage structures at disposal sites, especially after heavy rainfall events.
- Water quality monitoring: Regularly sample downstream of disposal sites at established monitoring points (SW-2) to verify the effectiveness of sedimentation ponds.

IESC #4: Soil Quality
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Short term	2	Medium term	2	
Frequency	Once	4	Irregular	2	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Definite	4	Unlikely	1	
Intensity	High	3	Medium	2	
Sum		18		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	Medium				
=					
SIGNIFICANCE	High		Low		

10.4.1.5 IESC #5 Land and Geology

Impacts pre-mitigation

Blasting poses a threat to cultural heritage. Lamche Bja (Elephant Cliff) is critically vulnerable to destabilization from blasting vibrations. Bunakha Lhakhang is vulnerable to cumulative vibration-induced structural damage.

Quarry development (INRQ-1, 2, and 3), tunnel excavation, and dam foundation excavation require extensive blasting and excavation, altering landforms.

The project relies on the Phuentsholing Highway and several access roads, including the road through Chanachen Village and the left-bank dam access road. Road improvement, widening, excavation, and construction activities in steep terrain may trigger localized slope instability, erosion, and failures within unconsolidated slope materials and existing debris deposits.

The left-bank dam access road crosses a nala where excavation and road construction activities may induce slope failures and erosion, particularly during the monsoon season when increased runoff can undermine retaining structures and destabilize debris deposits.

Seasonal monsoon conditions may increase the risk of minor landslides, debris accumulation, drainage-related erosion, and temporary road disruptions along access routes and within the Chanachen Village area, potentially affecting transportation and project logistics.

Improper placement or management of muck may contribute to slope instability, erosion, sediment transport, and localized alteration of landforms, particularly during periods of intense rainfall.

Mitigation Measures:

Preventive:

- Establish a communication channel among DGPC, BHPL, the Contractor, and the Ministry of Infrastructure and Transport to ensure uninterrupted access along the Phuentsholing Highway, particularly during the monsoon season.
- Implementation of slope stabilization measures, including the construction of gabion walls and masonry retaining structures, along road sections susceptible to slope instability.
- Construct masonry retaining walls along the left-bank dam access road where it crosses the nala and existing debris deposits.
- Conduct regular inspection and maintenance of retaining structures, particularly during and after the monsoon season.
- Minimize or avoid traveling along the left-bank dam access road during periods of intense rainfall.
- Contractor should prohibit mass, un-delayed blasting. Strictly calculate and limit the Maximum Charge per Delay (MIC) and use millisecond-delay detonators to ensure peak particle velocity (PPV) dissipates.
- Gabion toe walls: Construct robust toe walls at the base of all muck disposal sites prior to dumping to ensure slope stability.
-

Corrective:

- Real-Time Vibration Monitoring: Install continuous seismographs/vibration monitors at Bunakha Lhakhang, the base of Lamche Bja, and the nearest houses in Chanachen. Blasting parameters must be dialled back if vibrations approach safe thresholds.
- Progressive Revegetation: Re-vegetate completed surfaces with native species for stabilization and ecological integration.
- Geotechnical monitoring: Conduct regular inspection of slope stability at disposal sites.
- Reconstruct or reinforce retaining structures where damage or deterioration occurs due to runoff and erosion.
- Conduct regular inspection and maintenance of retaining structures, particularly during and after the monsoon season.
- Carry out routine maintenance of access roads and drainage systems to maintain year-round accessibility.

Stability Measures for Muck Disposal

Toe protection: Gabion toe walls and toe protection structures are mandated at the base of every MD site prior to any dumping, to resist outward slumping and provide a stable retaining face for placed material.

Controlled placement: Spoil is placed in engineered lifts with compaction and progressive grading rather than uncontrolled end-tipping, reducing the risk of internal shear failure and differential settlement.

Drainage control: Perimeter and diversion drain route clean hillslope runoff around each disposal site before dumping begins; sediment traps and sedimentation ponds are constructed at the toe to manage seepage and surface flow through the placed material, preventing pore-pressure build-up – a primary trigger of fill slope failure.

Progressive rehabilitation: Completed terraces are capped with stockpiled topsoil and stabilized immediately via bioengineering (hydroseeding, coir matting, native shrub planting) rather than left exposed until project completion, limiting the duration of peak instability risk.

Geotechnical surveillance: Weekly slope inspections, with mandatory additional checks after heavy rainfall events, monitor for visible signs of instability, toe wall condition, and drainage performance at MD-1, MD-2, and MD-4 – the largest and steepest sites – under the “IESC #5 Land and Geology – Muck Disposal Site Stability” monitoring indicator already defined in the ESMP Table 61- IESC #5 Land and Geology.

Tunnel Portal Slope Protection

Tunnel portal slopes for the BHPP will be excavated in weathered gneissic rock and are designed with a baseline slope inclination. Drainage measures, including catch drains, berm shotcrete protection, and 6 m long drain holes, are proposed to control surface runoff and reduce pore water pressures.

Initial portal stabilization will be provided using lattice girders, shotcrete, and systematic rock bolting, supplemented by a protective canopy to mitigate rockfall risks during early tunnel excavation. Support intensity will be varied based on rock mass conditions, with heavier support

(100 mm shotcrete and closer bolt spacing) in Grade III weathered rock and lighter support (50 mm shotcrete and wider bolt spacing) in Grade II rock.

Real-time monitoring using multi-point borehole extensometers will be installed to detect deformation and support early warning of instability. Controlled blasting with reduced charge weights and vibration monitoring will be strictly implemented during portal excavation to minimize disturbance.

A Tunnel Portal Failure Management Plan (TPFMP) will be implemented, including hazard identification, monitoring with trigger action response levels (TARLs), emergency response procedures, and post-failure remediation measures. These provisions ensure safe excavation, early risk detection, and adaptive stabilization of portal slopes during construction.

IESC #5: Land and Geology
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Long term	3	Long term	3	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Definite	4	Unlikely	1	
Intensity	High	3	Medium	2	
Sum		19		11	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Compensatory:

- Mandatory Pre-Construction Structural Survey: Conduct a comprehensive structural condition (dilapidation) survey of every residential, commercial, and religious structure within Chanachen and Bunakha villages, as well as the Lamche Bja cliff face, to establish a baseline for damage claims.

10.4.1.6 IESC #6 River Morphology

Impacts pre-mitigation

The construction program, comprising two diversion tunnels (each 9.5 m in diameter, measuring 860 m and 904 m in length), upstream cofferdams (crest elevation 1890 m), and extensive RCC works will significantly alter the river's natural flow regime and morphology.

During critical phases, the diversion will route the full 25-year flood discharge (1,822 m³/s) through the tunnels, leaving approximately 1 km of river channel, from the cofferdam to the tunnel outfall below the bridge to Chanachen bridge, completely dewatered.

Mitigation Measures:

BHPL will maintain a continuous, ecologically calculated minimum environmental flow through the diversion tunnels at all times to prevent dewatering of the river stretch.

IESC #6: River Morphology
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Medium term	2	Medium term	2	
Frequency	Once	1	Once	1	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	3	
Sum		12		10	
Magnitude of the impact	Medium		Medium		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	High		High		

- BHPL will deploy physical sediment barriers, such as turbidity curtains and settling basins within the diversion channels, to capture suspended solids before water is returned to the main river course.
- Sequence the plunge pool excavation and counter barrage construction to minimize concurrent sediment-generating activities.

10.4.2 Impacts on the biological environment

10.4.2.1 IESC#7: Protected Areas, Critical Habitat and Ecological Connectivity

Impacts pre-mitigation

Vegetation clearance, excavation, and infrastructure development will result in fragmentation of forest habitats and localized disruption of wildlife movement. Disturbances from noise, vibration,

lighting, and workforce presence may lead to temporary displacement and avoidance behavior among faunas. Increased accessibility due to construction activities may elevate the risk of human–wildlife interactions and opportunistic resource use.

Mitigation Measures:

- Restrict vegetation clearance strictly to approved footprint
- Maintain wildlife movement corridors and avoid unnecessary clearing
- Prohibit hunting and enforcing worker code of conduct
- Restrict night-time work in sensitive zones
- Implement anti-poaching awareness and support DoFPS patrols
- Control workforce movement and access to sensitive habitats

IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Wide range	4	Regional	3	
Duration	Long term	3	Long term	3	
Frequency	Repeated	4	Seasonal	3	
Ability to recover	Partially reversible	2	Partially Reversible	2	
Probability	Definite	4	Probable	3	
Intensity	High	3	Medium	2	
Sum		20		16	
Magnitude of the impact	High		High		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		Very High		

10.4.2.2 IESC#8: Terrestrial Habitats and Faunal Communities

Impact pre-mitigation

Vegetation clearance, excavation, slope cutting, and muck disposal will result in direct loss and modification of terrestrial habitats. Disturbances from noise, vibration, dust, and human presence may cause temporary displacement and behavioral changes in fauna. Habitat fragmentation and edge effects may alter habitat quality and increase exposure of wildlife to anthropogenic pressures.

Based on the assessment of impact magnitude prior to mitigation, construction-related impacts are regional in extent, long-term, and high in intensity due to habitat loss and disturbance,

resulting in a high magnitude of impact. Given the High sensitivity of the receptor, the impact significance is assessed as High.

Mitigation Measures:

- Restrict vegetation clearance strictly within approved footprint
- Conduct wildlife rescue, treatment, and relocation in coordination with DoFPS
- Implement progressive habitat restoration using native species
- Prohibit hunting and enforce worker code of conduct
- Minimize disturbance during sensitive breeding periods where practicable

IESC #8: Terrestrial Habitats and Faunal Communities Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	3	
Duration	Long term	3	Long term	3	
Frequency	Repeated	4	Seasonal	3	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Definite	4	Probable	3	
Intensity	High	3	Medium	2	
Sum		19		16	
Magnitude of the impact	High		High		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Implementation of mitigation measures reduces the magnitude of impact to Medium. However, due to permanent habitat loss, residual impacts remain significant, and the significance is assessed as High.

10.4.2.3 IESC#9: Aquatic Ecology and Environmental Flow Regime

Impacts pre-mitigation

In-stream works such as diversion, cofferdam installation, and dewatering may result in temporary increases in turbidity, sedimentation, and localized disturbance to aquatic habitats. Short-term impacts may include habitat disruption and potential fish mortality or displacement.

Based on the assessment of impact magnitude prior to mitigation, construction-related impacts on aquatic ecology are moderate in duration but repeated in occurrence, resulting in a high

magnitude of impact. Given the Very High sensitivity, the impact significance is assessed as Very High.

Mitigation Measures:

- Fish rescue and relocation during dewatering
- Avoid in-stream works during breeding periods
- Sediment and water quality control measures
- Pollution prevention and wastewater management

IESC #9: Aquatic Ecology and Environmental Flow Regime Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	2	
Duration	Mid term	2	Short term	1	
Frequency	Repeated	4	Seasonal	3	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Probable	3	
Intensity	Medium	2	low	1	
Sum		16		11	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		High		

Implementation of mitigation measures reduces the magnitude of impact to Medium. However, considering the sensitivity of aquatic systems, the residual significance remains High.

10.4.2.4 IESC#10: Riparian and Interface Ecosystems

Impacts pre-mitigation

Vegetation removal, slope cutting, and muck disposal near riverbanks may result in localized disturbance, erosion, and degradation of riparian habitats. These impacts are confined to narrow interface zones along the river corridor.

Based on the assessment of impact magnitude prior to mitigation, impacts are regional, long-term, and high in intensity, resulting in a High magnitude of impact. Considering receptor sensitivity, significance is High.

Mitigation Measures:

- Implement Greenbelt Development Plan

- Use native riparian species for plantation
- Apply bioengineering for slope stabilization
- Restore disturbed riparian zones

IESC #10: Riparian and Interface Ecosystems
Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Local	2	
Duration	Long term	3	Mid term	2	
Frequency	Repeated	4	Repeated	3	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Definite	4	Probable	3	
Intensity	High	3	Medium	2	
Sum		19		14	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Mitigation measures reduce the magnitude of impact to Medium; however, residual impacts remain significant, and the significance is assessed as High.

10.4.2.5 IESC#11: Flora, Pollinators and Invasive Species

Impacts pre-mitigation

Vegetation removal and soil disturbance will affect plant communities and associated pollinators. Disturbed areas may facilitate the introduction and spread of invasive species through material movement and site activities.

Based on the assessment of impact magnitude prior to mitigation, impacts are localized and medium-term, resulting in a medium magnitude of impact. Considering sensitivity, significance is High.

Mitigation Measures:

- Flora rescue and conservation of priority species
- Restoration using native and pollinator-friendly species
- Invasive species prevention and control

IESC #11: Flora, Pollinators and Invasive Species Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	2	Local	2	
Duration	Mid term	2	Short term	1	
Frequency	Repeated	4	Seasonal	3	
Ability to recover	Reversible	1	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	Medium	2	Low	1	
Sum		14		10	
Magnitude of the impact	Medium		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Mitigation measures reduce the magnitude of impact to Low. The residual significance is assessed as High.

10.4.2.6 IESC#12: Ecosystem Services and Functional Ecology

Impacts pre-mitigation

Vegetation clearance and land disturbance will affect regulating ecosystem services such as slope stabilization, erosion control, and sediment regulation. Supporting ecological processes may also be affected.

Based on the assessment of impact magnitude prior to mitigation, impacts are regional and long-term, resulting in a high magnitude of impact. Considering sensitivity, significance is High.

Mitigation Measures:

- Restore vegetation cover through afforestation
- Implement erosion control and slope stabilization
- Integrate biodiversity management plans

IESC #12: Ecosystem Services and Functional Ecology Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Municipal	2	
Duration	Long term	3	Medium term	2	

IESC #12: Ecosystem Services and Functional Ecology Impacts Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Frequency	Repeated	4	Seasonal	3	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Probable	3	Probable	3	
Intensity	High	3	Medium	2	
Sum		18		14	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Mitigation reduces the magnitude to Medium; however, residual ecological changes persist, and significance remains High.

10.5 Step 3 (c): Multi Criteria Analysis - Impacts and Mitigation Measures During Operation

The operation phase entails operation of the dam, water flow management, turbine operation, monitoring of generated energy, safety and emergency procedures, e-flow management, and sediment management activities.

10.5.1 Impacts on the physical environment

10.5.1.1 IESC #2 Noise

Impacts pre-mitigation

Continuous exposure of noise from turbine-generator sets; turbine hall levels can exceed 85 dBA causing occupational health hazards.
The villages like Chanachen, Nayaka, Bunakha, Lobnekha Heritage, Tshimalakha, Geling Goenpa, Nayatsen and Tsho Sacred Sites will be vulnerable due to its pristine environment, adjacent to main access road and sacred sites due to vehicular movements.

Mitigation Measures:

Preventive:

- BHPL will schedule high-noise maintenance activities during daytime hours and provide advance notification to communities. Provide adequate numbers of PPEs to workers such as ear plug in high noisy areas including powerhouse.
- Schedule maintenance activities during day time only.

Corrective:

- Regular health checkup for workers during operation phase.
- Provide acoustic insulation, modifying maintenance schedules, or installing silencers on equipment.

IESC #2: Noise
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Long term	3	Long term	3	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Unlikely	1	
Intensity	Medium	2	Low	1	
Sum		15		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				

IESC #2: Noise
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
=					
SIGNIFICANCE	High		Medium		

10.5.1.2 IESC #3 Water Quality

Impacts pre-mitigation

Hazardous waste such as oils, lubricants, greases, cooling water discharge, drainage from powerhouse sumps, and sanitary wastewater during powerhouse operation may affect water quality.

Mitigation Measures:

Preventive:

- All hazardous materials, including used oils, lubricants, and chemical wastes, will be stored in designated areas featuring: Impervious secondary containment: Bunded areas or double-walled tanks capable of holding 110% of the largest container volume to prevent spills from reaching the environment.
- Drainage from the powerhouse (including turbine pit dewatering) will pass through oil-water separators before discharge.
- Regular inspection of critical equipment including Turbine-generator sets, Oil systems, Cooling water systems and Electrical equipment
- Treated through appropriate sewage treatment facilities before disposal or reuse.

Corrective:

- Downstream monitoring at established sites (SW1 & SW-2) to detect any operational contamination.

IESC #3: Water Quality
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Long term	3	Long term	3	
Frequency	Irregular	4	Once	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Possible	4	Unlikely	1	
Intensity	Medium	2	Low	1	
Sum		15		9	
Magnitude of the impact	High		Low		
vs					

IESC #3: Water Quality
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

10.5.1.3 IESC #5 Land and Geology

Impacts pre-mitigation

The fluctuation of water levels, driven by the plant's peaking operation (targeting 6 hours of firm power generation daily) creates a pronounced drawdown zone of up to 56 m between FRL and MDDL. This fluctuating zone leads to bank erosion.

Mitigation Measures:

- To reduce bank erosion, the rate of reservoir drawdown and refilling will be technically limited to a maximum of 2.5 m per day maintaining bank stability

Corrective:

- A formal Reservoir Operation Manual will be developed, balancing power generation objectives with environmental requirements.
- While minimizing downstream flood impacts routed PMF (9,224 m³/s) and spillway gate operation (n-1 case) will be maintained.
- Regular bathymetric surveys of the reservoir will be conducted, as recommended in the hydrology studies, to monitor sediment deposition rates (estimated at 0.34 mm/year average) and assess the long-term evolution of the reservoir bed and delta formation.

IESC #5: Land and Geology
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	
Duration	Long term	3	Long term	3	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	High	3	Medium	2	
Sum		19		11	
Magnitude of the impact	High		Medium		

IESC #5: Land and Geology
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

10.5.1.4 IESC #6 River Morphology

Impacts pre-mitigation

The reservoir regulates flow below dam up to Chhukha HPP, attenuating floods and augmenting dry-season flows, which changes the hydrological character of the river downstream.

Mitigation Measures:

Real-time communication and operational coordination will be maintained with the downstream Chhukha HPP (336 MW) and Tala HPP (1020 MW) operators ensuring regulated releases from Bunakha are effectively utilized for power generation and do not cause operational issues or unnecessary spill at downstream facilities, as analyzed in the cascade operation studies.

IESC #6: River Morphology
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	3	
Duration	Long term	3	Long term	3	
Frequency	Repeatedly	4	Irregular	2	
Ability to recover	Partly reversible	2	Reversible	1	
Probability	Definite	4	Probable	3	
Intensity	Medium	2	Low	1	
Sum		18		13	
Magnitude of the impact	High		Medium		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		High		

Mitigation measures reduce uncertainty in impact extent; however, the magnitude remains High due to inherent hydrological modification, and significance remains High.

10.5.2 Impacts on the biological environment

10.5.2.1 IESC#7: Protected Areas, Critical Habitat and Ecological Connectivity

Impacts pre-mitigation

The reservoir and associated infrastructure will introduce long-term modifications to habitat structure and movement pathways. While ecological connectivity within the broader corridor landscape will remain, localized barriers and altered movement patterns may occur, potentially affecting species movement at the project scale.

Mitigation Measures

- Maintain ecological connectivity through afforestation and habitat restoration
- Monitor wildlife movement using camera traps
- Maintain buffer zones around reservoir and infrastructure
- Implement long-term biodiversity monitoring and adaptive management

IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	3	
Duration	Permanent	4	Permanent	4	
Frequency	Continuous	4	Continuous	4	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Definite	4	Probable	3	
Intensity	High	3	Medium	2	
Sum		20		18	
Magnitude of the impact	Very High		High		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		Very High		

10.5.2.2 IESC#8: Terrestrial Habitats and Faunal Communities

Impacts pre-mitigation

Partial ecological recovery may occur through natural regeneration and restoration; however, full recovery of original forest structure and habitat conditions is unlikely.

Based on the assessment of impact magnitude prior to mitigation, operational impacts are local in extent but permanent in duration, resulting in a High magnitude of impact. Considering the receptor sensitivity, the impact significance is assessed as High.

Mitigation Measures:

- Maintain restored habitat areas and monitor vegetation recovery
- Implement long-term wildlife monitoring (camera traps, transects)
- Maintain buffer zones around infrastructure

IESC #8: Terrestrial Habitats and Faunal Communities Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	2	Local	2	
Duration	Permanent	4	Permanent	4	
Frequency	Continuous	4	Seasonal	3	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Probable	3	Probable	3	
Intensity	Medium	2	Medium	2	
Sum		17		16	
Magnitude of the impact	High		High		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

With mitigation measures in place, the magnitude of impact is reduced to Medium. However, due to long-term habitat modification, the residual significance remains High.

10.5.2.3 IESC#9: Aquatic Ecology and Environmental Flow Regime

Impacts pre-mitigation

Flow regulation and reservoir formation will modify the hydrological regime, sediment transport processes, and aquatic habitat characteristics. Baseline studies indicate low fish abundance and limited evidence of active migration within the project stretch; therefore, impacts primarily affect habitat conditions rather than major migratory pathways. Conversion of riverine (lotic) conditions to reservoir (lentic) conditions will further alter habitat structure and ecological processes.

Based on the assessment of impact magnitude prior to mitigation, operational impacts are permanent and continuous, resulting in a Very High magnitude of impact. Given the Very High sensitivity, the impact significance is assessed as Very High (Critical).

Mitigation Measures:

- Maintain environmental flow regime
- Monitor aquatic ecology (CPUE, diversity)
- Manage sediment and water quality

IESC #9: Aquatic Ecology and Environmental Flow Regime Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Wide range	-4	Local	2	
Duration	Permanent	-4	Permanent	4	
Frequency	Continuous	-4	Seasonal	3	
Ability to recover	Irreversible	-4	Partially reversible	2	
Probability	Definite	-4	Probable	3	
Intensity	High	-3	Medium	2	
Sum		23		16	
Magnitude of the impact	Very High		High		
vs					
Sensitivity of the receptor	Very High				
=					
SIGNIFICANCE	Very High		Very High		

Mitigation measures reduce ecological stress; however, due to permanent hydrological alteration, the magnitude remains High and the residual significance remains Very High.

10.5.2.4 IESC#10: Riparian and Interface Ecosystems

Impacts pre-mitigation

Reservoir water level fluctuations will alter moisture regimes and affect vegetation stability and regeneration along reservoir margins. Due to steep terrain, the project area lacks developed floodplain systems; therefore, impacts are limited to narrow riparian corridors and river–land interface zones.

Based on the assessment of impact magnitude prior to mitigation, impacts are long-term and influenced by reservoir fluctuation, resulting in a High magnitude of impact.

Mitigation Measures:

- Maintain riparian vegetation along reservoir margins

- Monitor vegetation stability and regeneration

IESC #10: Riparian and Interface Ecosystems Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	3	
Duration	Permanent	4	Long term	3	
Frequency	Seasonal	3	Seasonal	3	
Ability to recover	Partially reversible	2	Partially reversible	2	
Probability	Probable	3	Probable	3	
Intensity	High	3	High	2	
Sum		18		16	
Magnitude of the impact	High		High		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		High		

Mitigation reduces the magnitude to Medium; however, hydrological changes persist, and significance remains High.

10.5.2.5 IESC#11: Flora, Pollinators and Invasive Species

Impacts pre-mitigation

Without appropriate management, disturbed habitats may continue to support invasive species, potentially affecting native vegetation structure and ecosystem functioning. Impacts on pollinators may persist where floral resources are reduced.

Based on the assessment of impact magnitude prior to mitigation, impacts are localized and seasonal, resulting in a medium magnitude of impact.

Mitigation Measures:

- Monitor invasive species spread
- Maintain vegetation cover and floral diversity

IESC #11: Flora, Pollinators and Invasive Species Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	2	Local	1	

IESC #11: Flora, Pollinators and Invasive Species Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Duration	Long term	3	Mid term	2	
Frequency	Seasonal	3	Occasional	2	
Ability to recover	Reversible	1	Reversible	1	
Probability	Possible	2	Possible	2	
Intensity	Low	1	Low	1	
Sum		12		9	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

Mitigation reduces impacts to Low magnitude, with residual significance assessed as Medium.

10.5.2.6 IESC#12: Ecosystem Services and Functional Ecology

Impacts pre-mitigation

Hydrological modification and land-use change will influence ecosystem functioning, including water regulation, sediment transport, and ecological interactions. Field observations indicate that local communities have limited dependence on forest and river-based ecosystem services due to their distance from the AoI; therefore, impacts are primarily ecological rather than socio-economic in nature.

Based on the assessment of impact magnitude prior to mitigation, impacts are long-term and continuous, resulting in a High to Very High magnitude.

Mitigation Measures:

- Maintain environmental flow
- Monitor ecosystem functions and restoration success

IESC #12: Ecosystem Services and Functional Ecology Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Regional	3	Regional	3	
Duration	Permanent	4	Long term	3	
Frequency	Repeatedly	4	Repeatedly	4	
Ability to recover	Partially reversible	2	Partially reversible	2	

IESC #12: Ecosystem Services and Functional Ecology Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Probability	Definite	4	Probable	3	
Intensity	High	3	Medium	2	
Sum		20		17	
Magnitude of the impact	Very High		High		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	Very High		High		

Mitigation reduces impacts to medium magnitude; however, long-term ecological changes remain, and significance is assessed as High.

10.6 Summary of the Environmental Impacts' Significance

This chapter presents a summary of the significance of the impacts expected to be delivered by the Project's pre-construction, construction, operation, and decommissioning on the environment. Whenever the significance post-mitigation is medium or high, the table indicates the need for compensation measures. Compensation and mitigation measures are defined in the ESMP (Chapter 13).

Table 57: Summary of the significance of the environmental impacts of the Bunakha HPP during pre-construction

PRE-CONSTRUCTION

Feature	Significance of the impacts		Compensation
	Pre-mitigation	Post-mitigation	
Physical Environment			
IESC#1 Air Quality	High	Medium	
IESC#2 Noise	High	Medium	
IESC#3 Water Quality	High	Medium	
IESC#4 Soil Quality	Medium	Low	
Biological Environment			
IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity	Very High	High	
IESC #8: Terrestrial Habitats and Faunal Communities	High	High	

IESC #9: Aquatic Ecology and Environmental Flow Regime	Very High	High

Table 58: Summary of the significance of the environmental impacts of the Bunakha HPP during construction

CONSTRUCTION

Feature	Significance of the impacts		Compensation
	Pre-mitigation	Post-mitigation	
Physical Environment			
IESC #1: Air Quality	High	Medium	
IESC #2: Noise	High	Medium	
IESC #3: Water Quality	High	High	
IESC #4: Soil Quality	High	Low	
IESC #5: Land and Geology	High	High	Mandatory Pre-Construction Structural Survey
IESC #6: River Morphology	High	High	
Biological Environment			
IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity	Very High	Very High	
IESC #8: Terrestrial Habitats and Faunal Communities	High	High	
IESC #9: Aquatic Ecology and Environmental Flow Regime	Very High	High	
IESC #10: Riparian and Interface Ecosystems	High	High	
IESC #11: Flora, Pollinators and Invasive Species	High	High	
IESC #12: Ecosystem Services and Functional Ecology	High	Medium	

Table 59: Summary of the significance of the environmental impacts of the Bunakha HPP during operation

OPERATION

Feature	Significance of the impacts		Compensation
	Pre-mitigation	Post-mitigation	
Physical Environment			
IESC #2: Noise	High	Medium	
IESC #3: Water Quality	High	Medium	
IESC #5: Land and Geology	High	High	
IESC #6: River Morphology	Very High	High	
Biological Environment			
IESC #7: Protected Areas, Critical Habitat and Ecological Connectivity	Very High	Very High	
IESC #8: Terrestrial Habitats and Faunal Communities	High	High	Regulation of Biodiversity Action Plan
IESC #9: Aquatic Ecology and Environmental Flow Regime	Very High	Very High	Regulation of E-flow management plan
IESC #10: Riparian and Interface Ecosystems	High	High	
IESC #11: Flora, Pollinators and Invasive Species	High	Medium	
IESC #12: Ecosystem Services and Functional Ecology	Very High	High	

11 Social Impact Assessment

The evaluation of socio-economic impacts often requires a considerable degree of subjective professional judgment, based on local context and previous project experience. This is primarily because data on potential socio-economic impacts consists not only of facts but also of individual and community perceptions and attitudes, often meaning that the impact will vary according to the individuals or communities involved.

Impacts are expected in the following phases:

- Pre-construction phase: this one-year phase includes land acquisition, construction of the Project roads and bridge, utilities setup (power, water, telecommunications), contractor mobilization, setting up of camps and offices, construction of batching & crushing plants, construction of workshop and maintenance facilities, construction of the storage yard, setting up of the explosives magazine and the RCC lab, and performing additional surveys and investigations that may be required.
- Construction phase: river diversion, infrastructure works, E&M and H&M works, TL works, dam and powerhouse foundation excavation, dam concreting, construction of plunge pool and counter barrage, diversion tunnel plugging,
- Operation Phase: operation of the dam, water flow management, turbine operation, monitoring of generated energy, safety and emergency procedures, e-flow management, sediment management
- Decommissioning Phase: re-assessing the technical, economic, environmental and social impacts; prepare a decommissioning plan; obtain necessary approvals for decommissioning; perform related stakeholder engagement; controlled water release; sediment management; removal of infrastructure (partial or full); restoration works; safety and waste management

Decommissioning of the Project is not foreseen within the current planning horizon, and no decision has been made regarding the eventual retirement of the hydropower facilities. In line with Bhutanese environmental regulations and the requirements of ADB's Safeguard Policy Statement (2009), a detailed assessment of social impacts and associated mitigation measures shall be prepared at the time when decommissioning is formally considered. Such an assessment shall reflect the regulatory framework, technical options, and community context prevailing at that future stage.

Given the long operational lifespan of hydropower infrastructure, it is neither feasible nor meaningful to predict specific decommissioning-related social impacts at this stage. However, the Project shall commit to ensuring that any future decommissioning activities will follow national legislation, obtain all required clearances, and be guided by good international industry practice, including the preparation of a Decommissioning Plan and associated social safeguards instruments.

In view of the above, the impact assessment follows the methodology described earlier consisting of three steps:

- Step 1: Distinguish positive and negative impacts
- Step 2: Dismiss non-significant impacts
- Step 3: Multi-criteria analysis for significant impacts pre- and post-mitigation:
  - Step 3(a): During pre-construction
  - Step 3(b): During construction

- Step 3(c): During operation

The multi-criteria analysis is based on the formula and matrix shown below:

Magnitude vs Sensitivity = Significance

SIGNIFICANCE		**Magnitude of the impact**			
		Very high	*High*	*Medium*	*Low*
Sensitivity of the receptor	*Low*	High	Medium	Low	Low
	Medium	High	High	Medium	Low
	High	Very high	High	High	Medium
	Very high	Very high	Very high	High	High

The sensitivity of the receptors has been classified earlier in this report (Chapter 0); the magnitude is classified below for each impact expected, and the respective significance based on these two criteria as well. This exercise is done pre- and post-mitigation.

The main objective of the mitigation measures is to reduce impacts to “low”. For those impacts whose significance post-mitigation remains medium, high or very high (“residual impacts”), compensation or off-set measures are defined whenever technically and financially feasible.

Cumulative impacts are separately assessed.

Social impacts associated with the Project may arise both directly from Project activities and indirectly through changes to environmental conditions. The assessment therefore considered the interaction between environmental and social receptors, including how changes in river flow, river morphology, land use, vegetation cover, biodiversity resources, access routes, and ecosystem services may influence local livelihoods, resource use patterns, cultural practices, community health and safety, and household well-being. Particular attention was given to potential impacts on agriculture, collection of forest products, access to natural resources, and other ecosystem service benefits relied upon by local communities. Findings from the environmental assessment chapters were therefore used as inputs to the social impact assessment to evaluate potential indirect and induced social effects.

11.1 Step 1: Distinguish Positive and Negative Impacts

The Project is expected to generate positive impacts on the local economy and livelihoods in terms of employment and skills enhancement, local business opportunities, and upgrades to existing infrastructure.

Most of the direct economic and employment impacts from the Project will occur during the construction phase. It is during this period that the Project will need to hire the most workers and purchase goods and services. The workforce can be divided into two segments:

1. People directly employed by contractors and sub-contractors needed to build the Project, and
2. People indirectly supplying goods and services needed to support the construction process, including food and transport services and support staff at worker’s camps.

In FGDs and KIIs, local stakeholders expressed that, as recipients of most of the impacts of the Project, they expect employment opportunities, as well as for goods, services, and supplies to be locally procured (see Chapter 5.1.4).

Support local businesses

An increase in population in the area due to immigration and workers is expected during Project's construction, which can provide opportunities for some local shops and businesses (goods and services suppliers) to increase their revenue. These include food and transport services and support staff at worker's camps.

Potentially, some residents have the opportunity to build houses to meet the demand for rental accommodation resulting from immigration to the area.

Direct employment during construction

The construction workforce will reach approximately1,000 workers at peak levels, and will consist of skilled, semi-skilled, and unskilled personnel - approximately 30% of which are expected to be composed of national citizens. The duration of employment for the construction workforce will vary, depending on the project component and the ability of workers to work on subsequent components.

Local workers are expected to be qualified to fill unskilled and semiskilled positions at first, while a limited number of people may be sufficiently qualified for skilled positions. Workers for semi-skilled and skilled positions may initially have to be recruited from elsewhere in the region and throughout the country, as necessary. Over time, however, local workers will be able to fill more of the semi-skilled and skilled positions, as on-the-job training will be provided by the Project to the local workforce, which will improve skills levels relevant to the Project.

This will be ensured through inclusion of local employment and skills-transfer requirements in the EPC Contractor's contract and CESMP/Labour Management procedures. The Contractor will be required to prepare a Local Employment and Training Plan before mobilization, identifying available unskilled, semi-skilled and skilled positions, priority recruitment procedures for qualified local workers, training needs, on-the-job training arrangements, and reporting indicators. Implementation will be monitored by ESHS through monthly labour reports, including number of local workers employed, type of positions, number of workers trained, women's participation, and progression from unskilled to semi-skilled positions where applicable.

During the operation phase, the contracts that were in place during the construction phase will be terminated and procurement opportunities will be centred around maintenance activities and providing goods and services to the Project. For those companies that meet eligibility criteria, become approved suppliers, and enter the supply chain, there may be long-lasting and sustained benefits to businesses and their employees through increased experience, capacity, and training. As such, during the operation phase there will be opportunity for local business growth and development.

Further, it is anticipated that the Project itself will bring about economic benefits associated with increased connectivity between project-affected villages and other population centres.

Skills upgrade during construction

During construction, sub-contractors and workers will have the opportunity to receive on-the-job training and enhance their construction skills, which should assist individuals and organizations to find work on other construction projects in Bhutan. Those who have worked on the Project will, therefore, have an advantage when seeking alternative jobs on similar projects due to the experience and any training received through this Project. Opportunities for women to take advantage of economic opportunities will require specific support.

Physically and/or economically displaced households will also be eligible for participation in a range of livelihoods training programs (details can be found in the Resettlement Plan), the benefits of which will go beyond the end of the construction phase.

Existing Road and bridge upgradation

The upgrading of the bridge along the Chanachen Farm Road, the 5.5 km Chanachen Farm Road, and the 2 km Bunagu Farm Road will improve year-round accessibility for the residents of Chanachen and Bunagu villages. The improved road infrastructure will facilitate safer and more reliable transportation of agricultural produce, reduce travel time and vehicle operating costs, enhance access to markets, schools, healthcare facilities, and other essential services, and improve emergency response during adverse weather conditions. Overall, the upgraded infrastructure is expected to contribute to the socio-economic development and improve the quality of life of the local communities.

11.1.1 Enhancement measures for positive impacts

The enhancement measures presented in this section were identified through a combination of stakeholder consultations, household surveys, focus group discussions, key informant interviews, field observations, and professional assessment undertaken during the ESIA process. Community members, local leaders, women participants, affected households, and government representatives highlighted a range of development priorities and opportunities that could complement the positive impacts generated by the Project.

The proposed enhancement measures are intended to maximize local benefits associated with employment, skills development, infrastructure improvement, community development, livelihood enhancement, and social wellbeing. Particular consideration has been given to opportunities that may benefit women, vulnerable groups, and local communities within the Project Area of Influence.

These measures represent recommendations arising from the ESIA process and provide a framework for consideration by BHPL during project implementation. The feasibility, timing, funding arrangements, and implementation mechanisms for specific enhancement measures will be determined by BHPL in consultation with relevant stakeholders and local authorities.

To maximize the project’s socio-economic benefits, enhancement measures are proposed focusing on ensuring that local communities are not just recipients but active partners in the Project's success. These strategies aim to create durable, equitable, and transformative economic opportunities that extend well beyond the construction and operational phases.

The following was identified through stakeholder engagement activities and were deemed to be included as recommendation. Targeted support shall be provided to ensure women can fully access and benefit from Project-related economic and job opportunities, including:

- Skills training: offering short, practical training programs for women in areas linked to Project employment or local supply chains (e.g., administration, hospitality, nursery management, tailoring, catering, culinary, environmental field assistance).
- Preferential hiring pathways - reserving a percentage of jobs for qualified women. The GVA&AP requires that at least 15% of local jobs are provided to women (see **Error! Reference source not found.**). Provision of gender-sensitive facilities (separate sanitation, safe accommodation, grievance channels) to make project employment more accessible to women (1 women toilet per 20 workers is a target of the GVA&AP - see **Error! Reference source not found.**).

Other enhancement measures[27] suggested are:

- Utilize a portion of the Project's operational revenue to establish a revolving fund managed by a community committee. The fund shall be loaned or granted for small community projects. As funds are repaid or new revenue is added, the fund “revolves” and becomes available again. The revolving fund shall foresee simplified or fast-track procedures for women-led proposals.
- Proactively manage the influx of up to 1,000 construction workers by enhancing local health infrastructure (e.g., upgrading the local Basic Health Unit) and implementing a community health and safety awareness program.

11.2 Step 2: Dismiss Non-Significant Impacts

Impacts on tourism

Currently, tourism within the Project area is virtually absent, with minimal external visitation. Currently, there is minimal tourist potential, resulting in a complete absence of tourist amenities in the communities. Therefore, no significant negative impacts on tourism are expected.

[27] These enhancement measures are recommendations made by the ESIA team to the Client and have no prior approval from the Client.

11.3 Step 3 (a): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Pre-Construction

The one-year pre-construction phase includes land acquisition, construction of the Project roads and bridge, utilities setup (power, water, telecommunications), contractor mobilization, setting up of camps and offices, construction of batching & crushing plants, construction of workshop and maintenance facilities, construction of the storage yard, setting up of the explosives magazine and the RCC lab, and performing additional surveys and investigations that may be required.

11.3.1 IESC #13: Land and Assets

Land acquisition and associated impacts on land-based assets arise from permanent and temporary project components. These include the dam and reservoir area, powerhouse and associated infrastructure, access and approach roads, contractor construction facilities, muck disposal areas, transmission infrastructure, and other ancillary project facilities required during construction and operation.

The Project requires a total of 1,139.84 acres of land. Of this, 1,108.46 acres (97%) is SRFL, for which no compensation is payable to private parties, and 31.38 acres (3%) is private land, acquired entirely and permanently within the reservoir submergence area.

Land Requirement by Category and Type of Requirement (acres)

Land Category	Permanent (ac)	Temporary (ac)	Total (ac)
State Reserved Forest Land	852.12	256.34	1,108.46
Private Land	31.38	0.00	31.38
Total	883.50	256.34	1,139.84

In total, 44 directly affected households (AHs) and 218 directly affected persons (APs) will experience impacts arising from the Project. This population comprises 30 titleholder households whose registered land, structures, trees or crops are acquired for the reservoir and associated works, and 18 non-titled households at Chanachen who lose access to fiddlehead (Nakey) collection areas within the submergence area without losing registered land (4 households are common to both groups). Of the 44 AHs, 35 are classified as Severely Affected Households (SAHs) experiencing physical displacement or the loss of 10% or more of their productive/income-generating assets and 9 are classified as Vulnerable Affected Households (VAHs). One household will experience physical displacement due to complete inundation of its residential house and homestead land.

Affected Households and Persons, by Category.

Category	Titleholder AHs	Non-titled resource users	Total
Affected households (AHs)	30	18 (4 overlap)	44
Affected persons (APs)	148	70	218
Severely affected households (SAHs)	24	11	35

Vulnerable affected households (VAHs)	9	—	9
Physically displaced households	1	—	1

In addition to land, the Project affects 21 structures belonging to 13 households which are predominantly fences and sheds, together with the permanent and semi-permanent residential structures and 1,714 trees across 18 species belonging to 9 of the 30 titleholder households.

Impacts pre-mitigation

The significance of the expected impacts on land and assets pre-mitigation is assessed as “high”. The impact on this high sensitive IESC is local in spatial extent, occurs once but results in a permanent change, is irreversible in nature, will definitely occur, and is considered high in intensity if no mitigation measures are applied.

Mitigation measures

Mitigation measures for land and asset impacts are structured around the ADB Safeguard Policy Statement (2009) mitigation hierarchy: avoid impacts wherever feasible; minimize unavoidable impacts through project design; and restore the incomes and living standards of affected persons where impacts cannot be avoided or further minimized.

Avoidance

The Project's site selection and engineering design were guided in the first instance by the principle of avoiding involuntary resettlement wherever feasible, consistent with ADB SPS (2009). Key avoidance measures include:

- optimization of the powerhouse design from a surface to an underground configuration, removing the associated surface footprint from private land;
- siting of muck disposal areas, quarries, contractor construction facilities, the explosives magazine, stockyards, and the transmission line corridor on State Reserved Forest Land rather than private land;
- exclusion of religious structures (including Bunakha Lhakhang and other Lhakhangs), community forests, and other common property resources from the Project footprint by design; and
- reduction, through successive engineering-layout optimization, of the number of affected titleholder households from an earlier estimate of 35 to 30.

Minimization

Where avoidance was not feasible, principally within the reservoir submergence area, whose footprint is intrinsic to the Project and could not be relocated by any layout alternative, impacts have been minimized through:

- confining permanent private-land acquisition to the minimum area required for the reservoir and directly associated works (31.38 acres, 3% of the Project's total land requirement);

- confining all temporary land occupation during construction on State Reserved Forest Land and private land that will be acquired in revisor submergence so that no private land is taken on a temporary basis; and
- providing affected households a minimum of 30 days' written notice before vacating any structure, and sequencing land-take by area so that acquisition and construction activities do not proceed ahead of compensation.

Restoration

Residual impacts that cannot be avoided or minimized are addressed through compensation and livelihood restoration measures set out in the Resettlement Plan (RP, Annex 9), applying the principle of full replacement cost. These include:

- compensation for permanent land acquisition at full replacement cost, with a choice between land-for-land, cash compensation, or a combination, at the affected household's election;
- compensation for structures at full replacement cost under the Bhutan Schedule of Rates, without depreciation or deduction for salvageable materials;
- compensation for trees and standing crops at the applicable land compensation rate, with a top-up where required to reach full replacement cost;
- provision of an alternate resource-access site, or livelihood-restoration support and a transition allowance, for households losing access to common property resources, including fiddlehead/NTFP collection areas;
- additional transition allowances, priority access to livelihood restoration, and skills-training support for Severely Affected Households (SAHs) and Vulnerable Affected Households (VAHs); and
- for the single physically displaced household, a choice between in-kind replacement housing or cash compensation for self-relocation, together with transitional, food-security, and moving allowances.

The objective of these measures, consistent with ADB SPS (2009), is to restore, and where possible improve, the incomes and living standards of affected persons to at least their levels prior to the Project.

Unforeseen impacts

Impacts on land and assets identified during implementation but not anticipated in this ESIA or the RP, including impacts inadvertently missed during the detailed measurement survey (DMS), or affecting households not captured in the enumerated baseline will be addressed through the following process:

- the impact will be assessed through an update to the census, inventory of losses, and/or social impact assessment, as relevant to its nature and scale;
- the Resettlement Plan will be revised to reflect the additional impact and the affected household(s), and the revised RP will be disclosed to the affected household(s) and cleared by ADB before any further works proceed in the affected area; and
- compensation and assistance will be paid to the affected household(s), consistent with this RP and ADB SPS (2009), applying the principle of full replacement cost without depreciation and without deduction for salvageable materials and with the objective that the incomes and living standards of the affected household(s) are restored to at least their pre-Project levels.

No works will proceed in an area affected by an unforeseen impact until this process has been completed for that area.

Summary table

IESC #13: Land and assets
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Compensation required Associated plan: Resettlement Plan (Annex 9), Gender and Vulnerability Assessment & Action Plan
Duration	Short term	1	Short term	1	
Frequency	Once	1	Once	1	
Ability to recover	Irreversible	4	Irreversible	4	
Probability	Definite	4	Definite	4	
Intensity	High	3	Medium	2	
Sum		14		13	
Magnitude of the impact	High		High		
vs					
Sensitivity of the receptor	Medium				
=					
SIGNIFICANCE	High		High		

The Project has sought to minimize land acquisition and associated resettlement impacts through optimization of project design, use of existing infrastructure where practicable, selection of stare reserved forest land where feasible, and avoidance of settled areas. Residual impacts that could not be avoided have been addressed through compensation, livelihood restoration, and assistance measures in accordance with national legislation and ADB Safeguard Policy Statement (2009).

11.3.2 IESC #14: Occupational Health and Safety (OHS)

Impacts pre-mitigation

The BHPP involves pre-construction activities that present significant occupational health and safety (OHS) risks, substantially exceeding those associated with conventional civil construction projects. Pre-construction works will include extensive earthworks, site levelling, blasting, slope stabilization, river diversion culvert construction, electrical works, and work at height. These activities expose workers to a range of hazards, including accidents involving heavy machinery, rockfalls and slope failures, blasting incidents, falls from height, electrocution, electrical fires, exposure to hazardous substances such as fuels and chemicals, injuries from manual handling of heavy materials, encounters with wildlife, and adverse weather conditions. In addition, inadequate sanitation and worker welfare facilities could result in occupational health risks and disease outbreaks. Given the nature and scale of these hazards, the potential consequences include severe injuries, permanent disabilities, multiple fatalities, and catastrophic structural

failures if risks are not effectively managed. Accordingly, the occupational health and safety impact during the pre-construction is assessed as having High significance prior to mitigation.

The adverse impact on occupational health and safety during the pre-construction phase of the Project is assessed as of high significance, as the associated risks have the potential to cause severe injuries and even fatalities.

Mitigation measures

Develop and implement an Occupational Health and Safety Management Plan (OHS Plan) refereeing 13.5.19 Environmental safeguard during construction (OHS) .

In light of the potential occupational health and safety risks, it is imperative that the Contractor ensures that necessary measures are in place and properly implemented to prevent accidents and health injuries through a comprehensive Occupational Health and Safety Management Plan (OHS Plan).

The OHS Plan must include various aspects of OHS, including, at a minimum, measures to ensure lodging, food and water supply for the workers, implement sanitation systems, manage waste and wastewater and maintain camp cleanliness. Specific measures to safeguard the health & safety of the workers at site should also include, but not be limited to:

- Definition of an organigram of roles and responsibilities related to OHS management at the site including at least the information about first aid trained staff and the site Health & Safety Manager
- Assure availability of site specific first aid equipment;
- Set up workplace safety rules. All workers are required to strictly follow safety rules in their working conditions;
- Provide personal protective equipment (PPE) for all staff according to their works. Personal protection equipment must be provided in good conditions to the workers comprising of basic elements such as helmets, safety boots, ear protection, and dust masks, as well as equipment appropriate for specific works such as working at heights, working in trenches, electrical works, among others. Periodically check and maintain all the equipment to make sure that it is in good condition for use;
- Demark, fence and secure all trenches and manholes;
- Usage of fences and barriers must be in place wherever needed and deemed practical;
- Secure parked trucks, vehicles or machines against unauthorized access and use;
- Place noticeboards in place at different locations highlighting the following information:
  - Mandatory PPE at site,
  - Name, location and contact of the Health & Safety Manager and the first aid trained staff at site,
  - Emergency phone number of the nearest fire brigade,
  - Emergency phone number of the nearest hospital,
  - Emergency phone number of the nearest police station,
  - H&S management breaches of the month (“catch of the month”),
  - Summary of the main safety requirements.
- Train staff in H&S topics, conduct daily toolbox talks, allow only qualified personnel for specific tasks;

- Execution of appropriate risk assessments with all needed actions to prevent workers from possible incidents and accidents;
- Follow the 13.5.21 Blasting Operation.

At BHPL Tier 1 level, a dedicated OHS Officer is assigned within the ESHS.

At PSC Tier 2 level, a dedicated OHS Specialist forms part of the PSC ESHS team staffing, responsible for day-to-day OHS supervision, compliance verification, and reporting to ESHS of BHPL (Figure 10).

The Contractor is additionally required to designate a site-level Health and Safety Manager and first-aid trained staff as part of the OHS Plan.

This three-tier OHS resourcing structure - Contractor H&S Manager, PSC OHS Specialist, and BHPL OHS Officer - ensures continuous site-level implementation, independent verification, and owner-level oversight throughout the construction phase.

Prepare and implement a comprehensive Emergency Preparedness and Response Plan (ERP), aligned with the Dam Safety Emergency Preparedness Plan (Section 13.5.3).

The ERP shall incorporate a Hazard Identification (HAZID) assessment, early warning systems with sirens and public announcements, emergency alarm activation procedures, worker and community evacuation protocols, fire prevention and response measures, hazardous material spill containment, first aid and medical response arrangements, details of evacuation zone, incident reporting and investigation procedures, and post-emergency recovery measures.

Regular training, awareness programmes, community drills, and full-scale emergency simulations shall be conducted in accordance with the Dam Safety Emergency Preparedness Plan to ensure preparedness of workers, contractors, local communities, and relevant authorities. The ERP shall be reviewed and updated periodically throughout the Project lifecycle.

Emergency response procedures should be planned and put in place through an Emergency Response Plan (ERP) to ensure that an injured individual will receive competent help as quickly as possible. The objective of the ERP is to safeguard the welfare of workers, visitors, and the general public at the Project site and surroundings.

As one of the primary steps in formulating an effective ERP, the Contractors shall conduct a hazard identification (HAZID) exercise. This process identifies potential emergency scenarios—such as fires, chemical spills, gas leaks, structural failures, or natural disasters—that could impact personnel, equipment, and the surrounding environment. Understanding potential risks will help determine necessary resources, develop appropriate plans, and establish procedures to prepare for emergencies.

The ERP shall be comprehensive, practical, and tailored to the identified risks during the HAZID exercise, as well as to the duration and intensity of the works. The ERP shall address at least the following key components:

- Warning and evacuation systems: Establish reliable alarm and communication systems to alert staff and initiate safe evacuation in case of emergencies.
- Coordination with public emergency services: Define clear protocols for contacting local/district fire departments, medical services, and other relevant authorities promptly.

- First aid capability: Ensure that trained personnel are available on-site to administer first aid and stabilize injured individuals until professional medical assistance arrives.
- Technical response team: Maintain staff who are knowledgeable about facility infrastructure and operational processes, capable of managing leaks, isolating hazardous areas, and minimizing damage.
- Fire control measures: Develop and implement fire prevention and firefighting protocols, including the use of appropriate extinguishing agents for different hazardous materials.
- Containment and spill management: Include procedures for controlling and cleaning up hazardous spills to prevent contamination of soil, water, and air.
- Emergency drills and training: Schedule regular drills to test the effectiveness of the ERP and ensure all personnel understand their roles during an emergency.
- Communication and reporting: Establish internal and external communication channels for timely reporting and documentation of incidents.

Provide and make accessible a transparent Grievance Mechanism for workers

A Workers Grievance Mechanism shall be established by the Contractor as defined in **Error! Reference source not found.** of this ESIA Report.

Develop and implement a Labor Management Plan - see Chapter 13.5.9.

Others

- Report and record any accidents, incidents and/or breach of relevant legislation;
- Prohibit recruiting children who are below the minimum age of 18 years whether to work directly or indirectly on the Project.
- Provisions for penalties in bid documents should be enforced to discourage non-compliance, and any unsafe conditions identified during inspections must be promptly corrected.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on OHS post-mitigation (residual impacts) is assessed as having medium significance. This highlights the need for strict monitoring and OHS safety enforcement during the works.

Summary table

IESC #14: OHS
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Associated plans: OHS Plan; Emergency Response Plan; Workers Grievance Mechanism; Labor Management Plan Medium significance of residual impacts reinforces the need for
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	High	3	Medium	2	
Sum		16		8	

Magnitude of the impact	High	Low	strict implementation and monitoring
vs			
Sensitivity of the receptor	High		
=			
SIGNIFICANCE	High	Medium	

11.3.3 IESC #15: Community Health and Safety

Impacts pre-mitigation

As with any project, there is potential for impacts to the nearby communities during the pre-construction of the Bunakha HPP.

The pre-construction phase requires transportation of equipment, supplies, and labour from India and Thimphu, significantly increasing traffic on the Thimphu-Phuentsholing Asian Highway and Chanachen Farm Road. Poor road conditions, lack of safety signage, and unfamiliarity of local residents with heavy vehicles increase the potential risk for accidents involving pedestrians, livestock, and other vehicles.

The construction of access roads and the Chanachen farm road (5.5 km) increases heavy vehicle movement, creating traffic hazards for pedestrians, particularly children from Chhukha Central School and patients accessing Tshimalakha Hospital located 1 - 1.2 km from the Project area.

The setting up of batching and crushing plants near Chanachen village generates dust, noise, and vibrations affecting agricultural land and the health of nearby residents, with Chanachen having a pristine acoustic environment.

The establishment of worker camps and contractor mobilization introduces the risk of communicable disease transmission and social friction between workers and host communities. The explosive magazine set up at Chanachen farm road junction (0.37 acres) introduces safety risks to the community, requiring strict security and safety protocols.

In addition to the risks posed by construction vehicles and machinery, there are potential hazards such as electric strikes, exposure to hazardous materials during site works and transport, and accidents causing falls, bruises, and wounds resulting from people entering the construction site.

It is expected that both foreign and national workers will collaborate in the Project's construction.

The influx of workers and interaction between the workforce and local communities may increase the risk of sexual exploitation, abuse, and harassment (SEAH), gender-based violence (GBV), and inappropriate behaviour affecting women, children, and vulnerable groups within the Project area. To address these risks, the Project will implement SEAH prevention and response measures through the ESMP, Labour Management Procedures, Workers' Code of Conduct, stakeholder engagement activities, and grievance redress mechanism (GRM). Measures will include mandatory worker induction and awareness training, enforcement of Codes of Conduct with disciplinary provisions, confidential and survivor-centred grievance handling procedures, awareness programs for workers and communities, and referral mechanisms to available support

services. Special attention will be given to protection of vulnerable groups and ensuring safe and accessible reporting channels.

Prevention measures are governed by the Labour Management Plan (Section 13.5.9), which require all contractors to prepare a Labour Influx Management Plan with specific SEAH/GBV prevention provisions, enforce a mandatory Workers' Code of Conduct containing explicit prohibitions on SEAH and GBV, and conduct mandatory worker induction training covering SEAH awareness, reporting obligations, and disciplinary consequences.

Mitigation measures

To mitigate the impacts, following preventive measures shall be undertaken by the contractor:

- Follow the Blasting Operation Plan - see Chapter 13.5.21.
- Conduct a pre-construction structural survey within 500 m of the quarry site, batching plants, and access road alignment in Chanachen and Bunakha villages, with photographic documentation and property owner acknowledgments.
- BHPL shall ensure explosives magazine is located at approved site (Chanachen farm road junction) with 500 m setback from human occupancy.
- Citizens are generally not expected to get close enough to the construction sites resulting in any hazards. However, the proximity to houses may enhance curiosity in some persons, especially in children. To make sure that the sites are not entered by unauthorized persons, the construction sites need to be fenced. The fences need to be kept in good conditions, and be repaired if damages or vandalism occur.
- A safety distance between the public and any eventually existing non-fenced areas of the Project site can be ensured by implementation of warning and prohibition signs to highlight clearly that the area is restricted and no access is allowed to unauthorized persons
- Induction to the workers, especially drivers to follow the traffic rules, together with regular supervision of violations or damages to the access roads to reduce the risk of accidents
- Development of accident prevention/emergency preparedness policy and measures in form of an Emergency Response Plan as detailed in Chapter 0 of this ESIA Report
- Develop and implement a Worker's Code of Conduct by the pre-construction contractor, of which the workers shall be informed. The Code of Conduct shall contain provisions such as:
  - "good neighbourhood" principle, e.g., the workers shall not cause disturbances to any surrounding community related to noise, littering, or vandalism;
  - prevention of gender-based violence and SEAH in the workplace and in the neighbouring communities;
  - any potential or actual conflicts with local communities shall be immediately reported to the site management, and direct confrontation between Project workers and community members shall be strictly prohibited.
- If Project haul routes overlap with public access roads, the Contractor shall implement mitigation measures to minimize disruption. These shall be part of a Traffic Management Plan to ensure safe and efficient flow of vehicles, noise control strategies to reduce construction-related disturbances, and clear signage to inform visitors of temporary changes.
- Implement the noise and air emissions mitigations measures identified in the respective sections of the ESIA report.

In addition to the measures described, it is important to keep open communication channels between the Contractor and the affected communities. One way of assuring this is granting of free and easy access to an independent and effective Grievance Mechanism for the community to be established by ESHS as defined in **Error! Reference source not found.** of this ESIA Report. Also regular consultations with stakeholders, including local communities, environmental organizations, and government agencies, should be maintained during the pre-construction stage (and throughout the Project's life cycle). This ensures that the Project stays aligned with both environmental conservation goals and the needs of local population. It also helps in monitoring Project impacts and fine-tuning mitigation efforts based on stakeholder feedback. This shall include as well disclosing relevant Project-related information to stakeholders, including informing the nearby communities about upcoming works and the associated risks.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on CHS post-mitigation can be assessed as having high significance. High significance of residual impacts reinforces the need for strict implementation and monitoring.

Summary table

IESC #15: CHS
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Associated plans: Blasting Operation Plan; Pre-construction structural survey; Emergency Response Plan; Worker's Code of Conduct; Traffic Management Plan; General Public Grievance Mechanism, Gender and Vulnerability Assessment & Action Plan. High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Reversible	1	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	High	3	Medium	2	
Sum		13		8	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	Very high				
=					
SIGNIFICANCE	Very high		High		

Prior to commencement of major construction activities, BHPL shall undertake a detailed Community Health and Safety (CHS) Risk Assessment and prepare a corresponding CHS Management Plan in line with the sub-management plans given in section 13.5.

The assessment shall identify populations and sensitive receptors potentially affected by construction activities and shall include population-at-risk mapping, traffic risk assessment and

modelling, blasting impact assessment including vibration influence zones, community exposure to construction-related hazards, emergency preparedness requirements, and mitigation measures necessary to reduce risks to acceptable levels. The findings shall be incorporated into the Traffic Management Plan, Blasting Management Plan, Emergency Preparedness and Response Plan, and other relevant management plans.

11.3.4 IESC #16: Infrastructures

Impacts pre-mitigation

Existing linear infrastructures - Bailey Bridge over Wangchu River, and national highway - will be realigned, improved, or even replaced. Specifically:

- Chanachen farm road - will provide 5.5 km access road to quarry and batching plants; has presently a narrow geometry and requires improvement; presently serves only the Chanachen village
- Bailey Bridge over Wagchu River - it is located over the Wangchhu River and has 8 MT capacity, which is inadequate for Project transportation needs; it requires replacement with a 40R capacity bridge
- National Highway - a 115 m section affected by dam excavation will need to be re-aligned towards the hillside

These works will cause disruption to usual travel, access and communication patterns in the affected villages, and may temporarily affect trade and businesses too. Dust, noise and traffic safety matters, as discussed in the section dedicated to CHS are also expected.

Other infrastructures located nearby the Project site may be affected as follows:

- Tshimalakha Hospital - Approximately 1 to 1.2 kms from the Bunakha HPP, this hospital serves the Project area. Emergency access is critical
- Chhukha Central School - This school has a large student population, and is located alongside project logistics routes; children are particularly vulnerable to traffic accidents

Mitigation measures

The Contractor shall be responsible for:

- Immediately cleaning spilled materials on access roads.
- Immediately repair damages to roads and bridges caused by Project-related movements
- Maintain uninterrupted access for Chanachen village through phased construction, temporary bypasses, or controlled traffic windows.
- Implement and develop a Traffic Management Plan, including speed limits, signage, and designated passing bays.
- Deploy traffic marshals near the Tshimalakha Hospital access points during peak construction periods.
- Dust suppression through regular water spraying, especially near homes and farms.
- Establish a Community Notification System (SMS, notice boards, village meetings) to inform residents of construction schedules and temporary closures and alternative routes
- Construct a temporary bridge or safe detour before dismantling the existing Bailey bridge to ensure continuous crossing.

- Schedule works outside peak agricultural and school commuting hours to minimize disruption.
- Always ensure emergency vehicle access with priority passage for ambulances.
- Coordinate with local businesses to avoid supply chain disruptions and maintain market access.
- Install barriers, reflectors, and lighting to protect road users during excavation and realignment.
- Provide safe pedestrian pathways for residents who rely on the highway for daily movement.

BHPL shall be responsible for:

- Providing and making accessible a transparent Grievance Mechanism for the community as defined in **Error! Reference source not found.** of this ESIA Report.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on infrastructures post-mitigation can be assessed as having medium significance. A medium residual significance reinforces the need for strict implementation and monitoring.

Summary table

IESC #16: Infrastructures
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Traffic Management Plan; a Community Notification System; General Public Grievance Mechanism Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Seasonal	3	
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	Medium	2	Low	1	
Sum		14		10	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.3.5 IESC #17: Cultural, Religious and Historical sites

Impacts pre-mitigation

Pre-construction phase poses indirect risks to culturally, historically and religiously significant sites within the Project area. These risks typically arise from increased movement of workers, machinery, land clearing, vibration, accidental damage, and unregulated access.

The following locations are identified as particularly vulnerable and require focused protection and management:

- Bunakha Lhakhang: A prominent temple situated on the eastern riverbank, directly adjacent to the main access road. Its visibility from the proposed quarry and proximity to traffic routes make it highly susceptible to construction-related noise, vibration, and dust.
- Lamche Bja (Elephant Cliff): A spiritually revered cliff located upslope from the proposed quarry. During the public consultation held in Chanachen in July 2025, community members identified this as a critical issue. They expressed significant fear that blasting could disturb protective deities, raising a primary spiritual and cultural concern, while also voicing geotechnical concerns about the stability of the cliff face.
- Lobnekha Heritage Village: Positioned 3–4 km north-northeast of the main activity zone, this settlement lies directly downwind. Prevailing wind patterns increase its exposure to airborne pollutants, including dust and combustion emissions.
- Nayatsen and Tsho Sacred Sites & Geling Goenpa: Located northwest of the Project site, these sacred sites and the active monastery share a downwind position. Baseline data indicates poor air dispersion and a quiet soundscape, making them highly sensitive to dust and low-frequency noise from blasting operations.

Several other cultural sites within the AoI are considered low-risk due to their distance from construction activities. These are located several kilometers upstream of the Bunakha HPP dam axis and consist of a cluster of temples and monasteries—such as Tshekha Lhakhang, Drawang Nubriphukey Lhakhang, Pagar Gonpa, and Dobi Chokhor Gang Lhakhang.

Beyond the physical risks to tangible structures, the construction phase poses some risks to intangible cultural heritage associated with these sites; however, these are expected to be minimal and manageable following below presented mitigation measures.

Mitigation measures

- Contractor shall integrate all heritage locations into the project GIS and final construction drawings to avoid accidental encroachment.
- Contractor shall formulate Chance Finds Procedure as part of ESMP before construction begins, and train all relevant workers on Chance Finds Procedure before site access.
- Contractor shall raise awareness of cultural sensitivity among workers.
- Follow the Cultural Heritage Management Plan
- All measures defined for minimization of dust and noise emissions, littering and wastewater management apply
- BHPL shall establish spiritual foundation with Lams of Bunakha Lhakhang and Geling Goenpa; recognize sites as spiritual guardians with ceremonies from groundbreaking through commissioning; support annual rituals and prayers for Project safety.
- Contractor shall include ICH awareness in worker induction training - specifically prohibiting worker interference with ongoing religious ceremonies, entry into sacred sites without permission, and disrespectful behaviour near culturally sensitive locations.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on culturally, historically and religiously significant sites post-mitigation can be assessed as having

medium significance. This significance level cannot be further reduced, despite the low magnitude of the post-mitigation impacts because the sensitivity of the receptor is high. A medium residual significance reinforces the need for strict implementation and monitoring.

Summary table

IESC #17: Cultural, Religious and Historical Sites Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Unlikely	1	
Intensity	Medium	2	Low	1	
Sum		16		7	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.4 Step 3 (b): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Construction

The 5-year construction phase consist of the main activities river diversion, infrastructure works, E&M and H&M works, TL works, dam and powerhouse foundation excavation, dam concreting, construction of plunge pool and counter barrage, and diversion tunnel plugging.

11.4.1 IESC #14: Occupational Health and Safety (OHS)

Impacts pre-mitigation

The Bunakha HPP involves construction activities that present significant occupational health and safety (OHS) risks, substantially exceeding those associated with conventional civil construction projects. Construction works will include extensive earthworks, site levelling, blasting, slope stabilization, river diversion culvert construction, electrical works, and work at height. These activities expose workers to a range of hazards, including accidents involving heavy machinery, rockfalls and slope failures, blasting incidents, falls from height, electrocution, electrical fires, exposure to hazardous substances such as fuels and chemicals, injuries from manual handling of heavy materials, encounters with wildlife, and adverse weather conditions. In addition, inadequate sanitation and worker welfare facilities could result in occupational health risks and disease outbreaks. Given the nature and scale of these hazards, the potential

consequences include severe injuries, permanent disabilities, multiple fatalities, and catastrophic structural failures if risks are not effectively managed. Accordingly, the occupational health and safety impact during the pre-construction is assessed as having High significance prior to mitigation.

The adverse impact on occupational health and safety during the pre-construction phase of the Project is assessed as of high significance, as the associated risks have the potential to cause severe injuries and even fatalities.

Mitigation measures

Develop and implement an Occupational Health and Safety Management Plan (OHS Plan) refereeing 13.5.19 Environmental safeguard during construction (OHS) .

In light of the potential occupational health and safety risks, it is imperative that the Contractor ensures that necessary measures are in place and properly implemented to prevent accidents and health injuries through a comprehensive Occupational Health and Safety Management Plan (OHS Plan).

The OHS Plan must include aspects of OHS, including, at a minimum, measures to ensure lodging, food and water supply for the workers, implement sanitation systems, manage waste and wastewater and maintain camp cleanliness. Specific measures to safeguard the health & safety of the workers at site should also include, but not be limited to:

- Definition of an organigram of roles and responsibilities related to OHS management at the site including at least the information about first aid trained staff and the site Health & Safety Manager
- Assure availability of site specific first aid equipment;
- Set up workplace safety rules. All workers are required to strictly follow safety rules in their working conditions;
- Provide personal protective equipment (PPE) for all staff according to their works. Personal protection equipment must be provided in good conditions to the workers comprising of basic elements such as helmets, safety boots, ear protection, and dust masks, as well as equipment appropriate for specific works such as working at heights, working in trenches, electrical works, among others. Periodically check and maintain all the equipment to make sure that it is in good condition for use;
- Demark, fence and secure all trenches and manholes;
- Usage of fences and barriers must be in place wherever needed and deemed practical;
- Secure parked trucks, vehicles or machines against unauthorized access and use;
- Place noticeboards in place at different locations highlighting the following information:
  - Mandatory PPE at site,
  - Name, location and contact of the Health & Safety Manager and the first aid trained staff at site,
  - Emergency phone number of the nearest fire brigade,
  - Emergency phone number of the nearest hospital,
  - Emergency phone number of the nearest police station,
  - H&S management breaches of the month (“catch of the month”),
  - Summary of the main safety requirements.

- Train staff in H&S topics, conduct daily toolbox talks, allow only qualified personnel for specific tasks;
- Execution of appropriate risk assessments with all needed actions to prevent workers from possible incidents and accidents;
- Follow the 13.5.21 Blasting Operation.
- Prior to any specialised works a method statement has to be developed by the contractor to be approved by the ESHS. At minimum Method statements are required detailing OHS requirements for the following activities:
  - working at height
  - working in enclosed spaces
  - Tunneling & underground works
  - Heavy lifting/cranes
  - River crossings
  - Slope instability / landslides
  - Electrical live works
  - Mechanical works
  - Hot works

At BHPL Tier 1 level, a dedicated OHS Officer shall be assigned within the ESHS (Table 16).

At PSC Tier 2 level, a dedicated OHS Specialist forms part of the PSC ESHS team staffing, responsible for day-to-day OHS supervision, compliance verification, and reporting to ESHS (Figure 10).

The Contractor is additionally required to designate a site-level Health and Safety Manager and first-aid trained staff as part of the OHS Plan.

This three-tier OHS resourcing structure - Contractor H&S Manager, PSC OHS Specialist, and DGPC OHS Officer - ensures continuous site-level implementation, independent verification, and owner-level oversight throughout the construction phase.

Prepare and implement a comprehensive Emergency Preparedness and Response Plan (ERP), aligned with the Dam Safety Emergency Preparedness Plan (Section 13.5.3).

The ERP shall incorporate a Hazard Identification (HAZID) assessment, early warning systems with sirens and public announcements, emergency alarm activation procedures, worker and community evacuation protocols, fire prevention and response measures, hazardous material spill containment, first aid and medical response arrangements, details of evacuation zone, incident reporting and investigation procedures, and post-emergency recovery measures.

Regular training, awareness programmes, community drills, and full-scale emergency simulations shall be conducted in accordance with the Dam Safety Emergency Preparedness Plan to ensure preparedness of workers, contractors, local communities, and relevant authorities. The ERP shall be reviewed and updated periodically throughout the Project lifecycle.

Emergency response procedures should be planned and put in place through an Emergency Response Plan (ERP) to ensure that an injured individual will receive competent help as quickly as possible. The objective of the ERP is to safeguard the welfare of workers, visitors, and the general public at the Project site and surroundings.

As one of the primary steps in formulating an effective ERP, the Contractors shall conduct a hazard identification (HAZID) exercise. This process identifies potential emergency scenarios—such as fires, chemical spills, gas leaks, structural failures, or natural disasters—that could impact personnel, equipment, and the surrounding environment. Understanding potential risks will help determine necessary resources, develop appropriate plans, and establish procedures to prepare for emergencies.

The ERP shall be comprehensive, practical, and tailored to the identified risks during the HAZID exercise, as well as to the duration and intensity of the works. The ERP shall address at least the following key components:

- Warning and evacuation systems: Establish reliable alarm and communication systems to alert staff and initiate safe evacuation in case of emergencies.
- Coordination with public emergency services: Define clear protocols for contacting local/district fire departments, medical services, and other relevant authorities promptly.
- First aid capability: Ensure that trained personnel are available on-site to administer first aid and stabilize injured individuals until professional medical assistance arrives.
- Technical response team: Maintain staff who are knowledgeable about facility infrastructure and operational processes, capable of managing leaks, isolating hazardous areas, and minimizing damage.
- Fire control measures: Develop and implement fire prevention and firefighting protocols, including the use of appropriate extinguishing agents for different hazardous materials.
- Containment and spill management: Include procedures for controlling and cleaning up hazardous spills to prevent contamination of soil, water, and air.
- Emergency drills and training: Schedule regular drills to test the effectiveness of the ERP and ensure all personnel understand their roles during an emergency.
- Communication and reporting: Establish internal and external communication channels for timely reporting and documentation of incidents.

Provide and make accessible a transparent Grievance Mechanism for workers

A Workers Grievance Mechanism shall be established by the Contractor as defined in **Error! Reference source not found.** of this ESIA Report.

Develop and implement a Labor Management Plan - see Chapter 13.5.9.

Others

- Report and record any accidents, incidents and/or breach of relevant legislation;
- Prohibit recruiting children who are below the minimum age of 18 years whether to work directly or indirectly on the Project.
- Provisions for penalties in bid documents should be enforced to discourage non-compliance, and any unsafe conditions identified during inspections must be promptly corrected.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on OHS post-mitigation (residual impacts) is assessed as having medium significance. This highlights the need for strict monitoring and OHS safety enforcement during the works.

Summary table

IESC #14: OHS
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Associated plans: OHS Plan; Emergency Response Plan; Workers Grievance Mechanism; Labor Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	High	3	Medium	2	
Sum		16		8	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.4.2 IESC #15: Community Health and Safety

Impacts pre-mitigation

As with any project, there is potential for impacts to the nearby communities during the pre-construction of the Bunakha HPP.

The construction phase requires transportation of equipment, supplies, and labour from India and Thimphu, significantly increasing traffic on the Thimphu-Phuentsholing Asian Highway and Chanachen Farm Road. Poor road conditions, lack of safety signage, and unfamiliarity of local residents with heavy vehicles increase the potential risk for accidents involving pedestrians, livestock, and other vehicles.

The construction of access roads and the Chanachen farm road (5.5 km) increases heavy vehicle movement, creating traffic hazards for pedestrians, particularly children from Chhukha Central School and patients accessing Tshimalakha Hospital located 1 - 1.2 km from the Project area.

The setting up of batching and crushing plants near Chanachen village generates dust, noise, and vibrations affecting agricultural land and the health of nearby residents, with Chanachen having a pristine acoustic environment.

The establishment of worker camps and contractor mobilization introduces the risk of communicable disease transmission and social friction between workers and host communities. The explosive magazine set up at Chanachen farm road junction (0.37 acres) introduces safety risks to the community, requiring strict security and safety protocols.

In addition to the risks posed by construction vehicles and machinery, there are potential hazards such as electric strikes, exposure to hazardous materials during site works and transport, and accidents causing falls, bruises, and wounds resulting from people entering the construction site.

It is expected that both foreign and national workers will collaborate in the Project's construction.

The influx of workers and interaction between the workforce and local communities may increase the risk of sexual exploitation, abuse, and harassment (SEAH), gender-based violence (GBV), and inappropriate behaviour affecting women, children, and vulnerable groups within the Project area. To address these risks, the Project will implement SEAH prevention and response measures through the ESMP, Labour Management Procedures, Workers' Code of Conduct, stakeholder engagement activities, and grievance redress mechanism (GRM). Measures will include mandatory worker induction and awareness training, enforcement of Codes of Conduct with disciplinary provisions, confidential and survivor-centred grievance handling procedures, awareness programs for workers and communities, and referral mechanisms to available support services. Special attention will be given to protection of vulnerable groups and ensuring safe and accessible reporting channels.

Prevention measures are governed by the Labour Management Plan (Section 13.5.9), which require all contractors to prepare a Labour Influx Management Plan with specific SEAH/GBV prevention provisions, enforce a mandatory Workers' Code of Conduct containing explicit prohibitions on SEAH and GBV, and conduct mandatory worker induction training covering SEAH awareness, reporting obligations, and disciplinary consequences.

Mitigation measures

To mitigate the impacts, following preventive measures shall be undertaken by the contractor:

- Follow the Blasting Operation Plan - see Chapter 13.5.21.
- Conduct a construction structural survey within 500 m of the quarry site, batching plants, and access road alignment in Chanachen and Bunakha villages, with photographic documentation and property owner acknowledgments.
- BHPL shall ensure explosives magazine is located at approved site (Chanachen farm road junction) with 500 m setback from human occupancy.
- Community members are not allowed to get close enough to the construction sites resulting in any hazards. However, the proximity to houses may enhance curiosity in some persons, especially in children. To make sure that the sites are not entered by unauthorized persons, the construction sites need to be fenced. The fences need to be kept in good conditions, and be repaired if damages or vandalism occur.
- A safety distance between the public and any eventually existing non-fenced areas of the Project site can be ensured by implementation of warning and prohibition signs to highlight clearly that the area is restricted and no access is allowed to unauthorized persons

- Induction to the workers, especially drivers to follow the traffic rules, together with regular supervision of violations or damages to the access roads to reduce the risk of accidents
- Development of accident prevention/emergency preparedness policy and measures in form of an Emergency Response Plan as detailed in Chapter 0 of this ESIA Report
- Develop and implement a Worker's Code of Conduct by the pre-construction contractor, of which the workers shall be informed. The Code of Conduct shall contain provisions such as:
  - "good neighbourhood" principle, e.g., the workers shall not cause disturbances to any surrounding community related to noise, littering, or vandalism;
  - prevention of gender-based violence and SEAH in the workplace and in the neighbouring communities;
  - any potential or actual conflicts with local communities shall be immediately reported to the site management, and direct confrontation between Project workers and community members shall be strictly prohibited.
- If Project haul routes overlap with public access roads, the Contractor shall implement mitigation measures to minimize disruption. These shall be part of a Traffic Management Plan to ensure safe and efficient flow of vehicles, noise control strategies to reduce construction-related disturbances, and clear signage to inform visitors of temporary changes.
- Implement the noise and air emissions mitigations measures identified in the respective sections of the ESIA report.

In addition to the measures described, it is important to keep open communication channels between the Contractor and the affected communities. One way of assuring this is granting of free and easy access to an independent and effective Grievance Mechanism for the community to be established by BHPL as defined in **Error! Reference source not found.** of this ESIA Report. Also regular consultations with stakeholders, including local communities, environmental organizations, and government agencies, should be maintained during the pre-construction stage (and throughout the Project's life cycle). This ensures that the Project stays aligned with both environmental conservation goals and the needs of local population. It also helps in monitoring Project impacts and fine-tuning mitigation efforts based on stakeholder feedback. This shall include as well disclosing relevant Project-related information to stakeholders, including informing the nearby communities about upcoming works and the associated risks.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on CHS post-mitigation can be assessed as having high significance. High significance of residual impacts reinforces the need for strict implementation and monitoring.

Summary table

IESC #15: CHS
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Associated plans: Blasting Operation Plan; Pre-construction structural survey;
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	

Ability to recover	Reversible	1	Reversible	1	Emergency Response Plan; Worker's Code of Conduct; Traffic Management Plan; General Public Grievance Mechanism, Gender and Vulnerability Assessment & Action Plan.
Probability	Probable	3	Possible	2	
Intensity	High	3	Medium	2	
Sum		13		8	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	Very high				High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
=					
SIGNIFICANCE	Very high		High		

Prior to commencement of major construction activities, BHPL shall undertake a detailed Community Health and Safety (CHS) Risk Assessment and prepare a corresponding CHS Management Plan in line with the sub-management plans given in section 13.5.

The assessment shall identify populations and sensitive receptors potentially affected by construction activities and shall include population-at-risk mapping, traffic risk assessment and modelling, blasting impact assessment including vibration influence zones, community exposure to construction-related hazards, emergency preparedness requirements, and mitigation measures necessary to reduce risks to acceptable levels. The findings shall be incorporated into the Traffic Management Plan, Blasting Management Plan, Emergency Preparedness and Response Plan, and other relevant management plans.

11.4.3 IESC #16: Infrastructures

Impacts pre-mitigation

Existing linear infrastructures - Bailey Bridge over Wangchu River, and national highway - will be realigned, improved, or even replaced. Specifically:

- Chanachen farm road - will provide 5.5 km access road to quarry and batching plants; has presently a narrow geometry and requires improvement; presently serves only the Chanachen village
- Bailey Bridge over Wagchu River - it is located over the Wangchhu River and has 8 MT capacity, which is inadequate for Project transportation needs; it requires replacement with a 40R capacity bridge
- National Highway - a 115 m section affected by dam excavation will need to be re-aligned towards the hillside

These works will cause disruption to usual travel, access and communication patterns in the affected villages, and may temporarily affect trade and businesses too. Dust, noise and traffic safety matters, as discussed in the section dedicated to CHS are also expected.

Other infrastructures located nearby the Project site may be affected as follows:

- Tshimalakha Hospital - Approximately 1 to 1.2 kms from the BHPP, this hospital serves the Project area. Emergency access is critical
- Chhukha Central School - This school has a large student population, and is located alongside project logistics routes; children are particularly vulnerable to traffic accidents

Mitigation measures

The Contractor shall be responsible for:

- Immediately cleaning spilled materials on access roads.
- Immediately repair damages to roads and bridges caused by Project-related movements
- Maintain uninterrupted access for Chanachen village through phased construction, temporary bypasses, or controlled traffic windows.
- Implement and develop a Traffic Management Plan, including speed limits, signage, and designated passing bays.
- Deploy traffic marshals near the Tshimalakha Hospital access points during peak construction periods.
- Dust suppression through regular water spraying, especially near homes and farms.
- Establish a Community Notification System (SMS, notice boards, village meetings) to inform residents of construction schedules and temporary closures and alternative routes
- Construct a temporary bridge or safe detour before dismantling the existing Bailey bridge to ensure continuous crossing.
- Schedule works outside peak agricultural and school commuting hours to minimize disruption.
- Always ensure emergency vehicle access with priority passage for ambulances.
- Coordinate with local businesses to avoid supply chain disruptions and maintain market access.
- Install barriers, reflectors, and lighting to protect road users during excavation and realignment.
- Provide safe pedestrian pathways for residents who rely on the highway for daily movement.

BHPL shall be responsible for:

- Providing and making accessible a transparent Grievance Mechanism for the community as defined in **Error! Reference source not found.** of this ESIA Report.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on infrastructures post-mitigation can be assessed as having medium significance. A medium residual significance reinforces the need for strict implementation and monitoring.

Summary table

IESC #16: Infrastructures
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Traffic Management Plan; a
Duration	Short term	1	Short term	1	

Frequency	Repeatedly	4	Seasonal	3	Community Notification System; General Public Grievance Mechanism Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Ability to recover	Reversible	1	Reversible	1	
Probability	Definite	4	Possible	2	
Intensity	Medium	2	Low	1	
Sum		14		10	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.4.4 IESC #17: Cultural, Religious and Historical sites

Impacts pre-mitigation

Construction phase poses indirect risks to culturally, historically and religiously significant sites within the Project area. These risks typically arise from increased movement of workers, machinery, land clearing, vibration, accidental damage, and unregulated access.

The following locations are identified as particularly vulnerable and require focused protection and management:

- Bunakha Lhakhang: A prominent temple situated on the eastern riverbank, directly adjacent to the main access road. Its visibility from the proposed quarry and proximity to traffic routes make it highly susceptible to construction-related noise, vibration, and dust.
- Lamche Bja (Elephant Cliff): A spiritually revered cliff located upslope from the proposed quarry. During the public consultation held in Chanachen in July 2025, community members identified this as a critical issue. They expressed significant fear that blasting could disturb protective deities, raising a primary spiritual and cultural concern, while also voicing geotechnical concerns about the stability of the cliff face.
- Lobnekha Heritage Village: Positioned 3–4 km north-northeast of the main activity zone, this settlement lies directly downwind. Prevailing wind patterns increase its exposure to airborne pollutants, including dust and combustion emissions.
- Nayatsen and Tsho Sacred Sites & Geling Goenpa: Located northwest of the Project site, these sacred sites and the active monastery share a downwind position. Baseline data indicates poor air dispersion and a quiet soundscape, making them highly sensitive to dust and low-frequency noise from blasting operations.

Several other cultural sites within the AoI are considered low-risk due to their distance from construction activities. These are located several kilometers upstream of the Bunakha HPP dam axis and consist of a cluster of temples and monasteries—such as Tshekha Lhakhang, Drawang Nubriphukey Lhakhang, Pagar Gonpa, and Dobi Chokhor Gang Lhakhang.

Beyond the physical risks to tangible structures, the construction phase poses some risks to intangible cultural heritage associated with these sites; however, these are expected to be minimal and manageable following below presented mitigation measures.

Mitigation measures

- Contractor shall integrate all heritage locations into the project GIS and final construction drawings to avoid accidental encroachment.
- Contractor shall formulate Chance Finds Procedure as part of ESMP before construction begins, and train all relevant workers on Chance Finds Procedure before site access.
- Contractor shall raise awareness of cultural sensitivity among workers.
- Follow the Cultural Heritage Management Plan
- All measures defined for minimization of dust and noise emissions, littering and wastewater management apply
- BHPL shall establish spiritual foundation with Lams of Bunakha Lhakhang and Geling Goenpa; recognize sites as spiritual guardians with ceremonies from groundbreaking through commissioning; support annual rituals and prayers for Project safety.
- Contractor shall include ICH awareness in worker induction training - specifically prohibiting worker interference with ongoing religious ceremonies, entry into sacred sites without permission, and disrespectful behaviour near culturally sensitive locations.

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on culturally, historically and religiously significant sites post-mitigation can be assessed as having medium significance. This significance level cannot be further reduced, despite the low magnitude of the post-mitigation impacts because the sensitivity of the receptor is high. A medium residual significance reinforces the need for strict implementation and monitoring.

Summary table

IESC #17: Cultural, Religious and Historical Sites
Impacts Pre-Construction

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Short term	1	Short term	1	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Unlikely	1	
Intensity	Medium	2	Low	1	
Sum		16		7	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				

=		
SIGNIFICANCE	High	Medium

11.5 Step 3 (c): Multi Criteria Analysis - Social Impacts and Mitigation Measures During Operation

The operation phase entails operation of the dam, water flow management, turbine operation, monitoring of generated energy, safety and emergency procedures, e-flow management, and sediment management activities.

The impacts on IESC #13 (Land & Assets) are expected to be delivered during pre-construction only and therefore do not apply for the operation stage. Notwithstanding this, activities under the Livelihood Restoration Plan (LRP) shall continue during this phase to support affected households whose livelihoods were impacted by land acquisition during construction. The Land Act of Bhutan 2007 and ADB Safeguard Policy Statement (2009) mandate continued livelihood support for affected persons until their living standards are fully restored.

Impacts delivered on IESC#16 (Infrastructure) are expected to be non-significant as transportation needs and circulation of heavy vehicles related to the Project dramatically reduce during operation. Therefore, it is not necessary to classify the related impacts.

11.5.1 IESC #14: Occupational Health and Safety (OHS)

Impacts pre-mitigation

During the operation phase, the Project will employ approximately 84 operational staff who will be exposed to occupational hazards including high-voltage electrical equipment (11 kV generation, 220 kV transmission line), rotating machinery (turbines and generators operating at 333.33 rpm), confined spaces (draft tube, spiral case), noise exposure (turbine hall levels exceeding 85 dBA), and fire risks from oil systems and electrical equipment. Workers also face risks from working at heights during maintenance of dam structures, and transmission towers.

Mitigation measures

Given the high risks inherent in hydropower operations, preventive measures including safety training, PPE, and emergency planning are essential to protect workers throughout the operational life of the project.

- BHPL shall prepare and implement an Occupational Health and Safety Plan for operations.
- BHPL shall conduct regular safety training and drills for all 84 personnel.

Impacts post-mitigation

After applying the proposed mitigation measures, the Project's residual impact on OHS is assessed as being of medium significance. This level cannot be reduced further, even though the post-mitigation impact magnitude is low, because the sensitivity of the affected receptors remains high. A medium residual significance underscores the importance of strict implementation and continuous monitoring of the mitigation measures.

Summary table

IESC #14: OHS Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Local	1	Local	1	Associated plans: OHS Plan for operation Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Long term	2	Long term	2	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	High	3	Medium	2	
Sum		17		9	
Magnitude of the impact	High		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.5.2 IESC #15: Community Health and Safety

Impacts pre-mitigation

During the operation phase, the Project requires ongoing maintenance of access roads (including the permanent access tunnel to the powerhouse), the transmission line, and other Project facilities. For example, the 220 kV transmission line will require periodic inspection and vegetation clearance along the corridor.

The newly created reservoir creates a 56 m drawdown zone (between FRL 2006m and MDDL 1950m) with bank erosion and unstable slopes. Operation of the 205 m high dam poses risks of dam failure, which could cause catastrophic downstream flooding affecting Chanachen, Bunakha, Nayakha, and all communities to Chhukha Dam (3.25 km downstream).

The presence of the reservoir introduces additional CHS concerns, including the risk of drowning, unsafe swimming or fishing practices, and increased mosquito breeding in shallow or stagnant areas. Water level fluctuations may create unstable shorelines, sudden currents, or exposed slopes that can endanger community members who may start using the reservoir for recreation, fishing, religious practices or collecting natural resources.

The dam's operational regime may also influence downstream safety, as rapid or unanticipated releases can affect river users, including farmers, herders, and religious practitioners who conduct rituals near the water. Rapid changes in flow during peaking operations create drowning risks in areas immediately upstream of the dam (headrace intake), and below the tailrace tunnel. Reservoir water level fluctuations (max 2.5 m/hr) could trigger landslides on reservoir margins.

Natural disasters including floods, earthquakes, and landslides continue to pose risks to communities and Project infrastructure.

Noise from periodic maintenance, vegetation clearance along the transmission line corridor, and occasional blasting or slope stabilization works may disturb nearby settlements and sensitive receptors. Together, these factors highlight that, although operational impacts are less intense than during construction, they still require careful management to safeguard community health and safety throughout the Project's lifespan.

Although traffic volumes will be significantly lower than during construction, routine vehicle movements will continue to pose risks to pedestrians and livestock.

Mitigation measures

- Maintain an updated Dam Break Analysis, Emergency Preparedness and Disaster Management Plan covering dam safety, floods, landslides, fires, and hazardous material incidents.
- Establish clearly marked safety zones around the reservoir, especially near steep or unstable shorelines.
- Install warning signs indicating drowning risks, sudden water level changes, and restricted areas.
- Conduct community awareness programs on safe fishing, boating, and swimming practices.
- Provide designated safe access points for community members who may use the reservoir for livelihood or recreation.
- Maintain a transparent water release schedule and communicate it regularly to downstream communities.
- Install early warning systems (sirens, SMS alerts, visual signals) for sudden or emergency releases.
- Coordinate with local authorities to ensure safe access to riverbanks for farmers, herders, and religious practitioners.
- Conduct periodic downstream safety drills with communities.
- Maintain the Grievance Redress Mechanism for community members to report CHS concerns.
- Periodic inspection and vegetation clearance along the transmission corridor

Impacts post-mitigation

Despite the implementation of the recommended mitigation measures, the residual impact on community health and safety remains of high significance. Although the magnitude of the post-mitigation impacts is reduced to low, the overall significance cannot be lowered further because the affected receptors are highly sensitive, particularly vulnerable groups such as schoolchildren, hospital users, and communities living near operational routes and the reservoir.

The persistence of a high residual significance highlights the need for strict adherence to mitigation measures, continuous monitoring, and proactive engagement with local communities throughout the operation phase.

Summary table

IESC #15: CHS
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Dam Break Analysis, Emergency Preparedness and Disaster Management Plan, General Public Grievance Mechanism
Duration	Long term	2	Long term	2	
Frequency	Repeatedly	4	Occasionally or never	1	
Ability to recover	Irreversible	4	Reversible	1	
Probability	Probable	3	Possible	2	
Intensity	High	3	Low	1	
Sum		18		9	
Magnitude of the impact	High		Low		High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
vs					
Sensitivity of the receptor	Very high				
=					
SIGNIFICANCE	Very high		High		

Consideration of Downstream Communities and River Users

Communities located along the downstream reaches of the Wangchhu River were considered during the environmental and social assessment process due to their potential exposure to changes in river flow conditions, construction-related disturbances, and operational safety risks associated with the Project. Consultations undertaken during the ESIA process included discussions with local communities, government representatives, and other stakeholders regarding river use, water resources, community safety, cultural values, and potential downstream impacts.

Stakeholders identified a range of existing river uses, including domestic water use, livestock watering, religious and cultural activities, recreation, and limited livelihood-related activities associated with the river corridor. Concerns raised during consultations primarily related to maintenance of adequate downstream flows, public safety during project operation, protection of cultural values associated with the river, and potential cumulative impacts arising from hydropower development within the Wangchhu cascade.

The Project incorporates environmental flow releases designed to maintain ecological functions and support downstream river uses. Environmental flow requirements have been assessed through hydrological and ecological studies and are further addressed through the Environmental Flow Management Plan. In addition, downstream public safety measures, emergency preparedness procedures, stakeholder communication mechanisms, and warning systems have been incorporated into project planning to reduce risks associated with operational flow fluctuations and emergency situations.

Based on the available information, the Project is not expected to result in significant adverse impacts on downstream community livelihoods provided that environmental flow requirements,

safety measures, and mitigation commitments are implemented effectively. Nevertheless, downstream conditions will continue to be monitored during project implementation and operation, and stakeholder feedback will be incorporated through ongoing engagement and grievance management mechanisms.

11.5.3 IESC #17: Cultural, Religious and Historical sites

Impacts pre-mitigation

The long-term presence and operation of a large dam and reservoir may indirectly affect nearby cultural, historical, and religious sites. Changes in landscape character, altered access routes, and increased human activity around the reservoir can influence the cultural setting and spiritual value of certain locations. Water level fluctuations may affect traditional river-based practices, while noise from operational activities or maintenance works may disturb the tranquility of sacred areas.

Furthermore, the reservoir may attract visitors, workers, or opportunistic resource users, increasing the risk of unregulated access, vandalism, or inadvertent disturbance to culturally sensitive sites.

Mitigation measures

- Schedule noisy maintenance activities (vegetation clearance, equipment testing, tunnel maintenance) outside of religious festivals, prayer times, or community ceremonies.
- Maintain regular communication with local monks, village elders, and cultural authorities to identify emerging concerns or new cultural practices linked to the reservoir.
- Implement a Chance Finds Procedure during all maintenance works, including vegetation clearance and shoreline inspections.
- Follow the Cultural Heritage Management Plan

Impacts post-mitigation

Following implementation of the recommended mitigation measures, the Project's impact on cultural, religious and historical sites post-mitigation can be assessed as having medium significance. This significance level cannot be further reduced, despite the low magnitude of the post-mitigation impacts because the sensitivity of the receptor is high. A medium residual significance reinforces the need for strict implementation and monitoring.

Summary table

IESC #17: Cultural, Religious and Historical Sites
Impacts Operation

Criteria	PRE-MITIGATION		POST-MITIGATION		Notes
	Classification	Scoring	Classification	Scoring	
Spatial extent	Municipal	2	Municipal	2	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
Duration	Long term	3	Long term	3	
Frequency	Seasonal	3	Occasionally or never	1	
Ability to recover	Reversible	1	Reversible	1	
Probability	Possible	2	Unlikely	1	
Intensity	Medium	2	Low	1	
Sum		13		9	
Magnitude of the impact	Medium		Low		
vs					
Sensitivity of the receptor	High				
=					
SIGNIFICANCE	High		Medium		

11.6 Summary of the Social Impacts' Significance

This chapter presents a summary of the significance of the impacts expected to be delivered by the Project's pre-construction, construction, and operation on the social environment. Whenever the significance post-mitigation is medium or high, the table indicates the need for compensation or other measures. Compensation and mitigation measures are defined in the ESMP (Chapter 13).

Table 60: Summary of the significance of the social impacts of the Bunakha HPP

IESC	Significance of the impacts		Notes
	Pre-mitigation	Post-mitigation	
PRE-CONSTRUCTION			
#13: Land and Assets	High	High	It is not unusual that, in cases of impacts on land and assets, compensation measures need to applied to tackle residual impacts. Compensation required Associated plan: Resettlement Plan (Annex 9)
#14: Occupational Health and Safety (OHS)	High	Medium	Associated plans: OHS Plan; Emergency Response Plan; Workers Grievance Mechanism; Labor Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
15: Community Health and Safety	Very high	High	Associated plans: Blasting Operation Plan; Pre-construction structural survey; Emergency Response Plan; Worker's Code of Conduct; Traffic Management Plan; General Public Grievance Mechanism High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
#16: Infrastructures	High	Medium	Associated plans: Traffic Management Plan; a Community Notification System; General Public Grievance Mechanism Medium significance of residual impacts reinforces the need for strict implementation and monitoring
#17: Cultural, Religious and Historical sites	High	Medium	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
CONSTRUCTION			
#13: Land and Assets	N.A.	N.A.	Impacts are expected to be delivered during pre-construction only

IESC	Significance of the impacts		Notes
	Pre-mitigation	Post-mitigation	
#14: Occupational Health and Safety (OHS)	High	Medium	Associated plans: OHS Plan; Emergency Response Plan; Workers Grievance Mechanism; Labor Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
#15: Community Health and Safety	Very high	High	Associated plans: Blasting Operation Plan; Pre-construction structural survey; Emergency Response Plan; Worker's Code of Conduct; Traffic Management Plan; General Public Grievance Mechanism High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
#16: Infrastructures	High	Medium	Associated plans: Traffic Management Plan; a Community Notification System; General Public Grievance Mechanism Medium significance of residual impacts reinforces the need for strict implementation and monitoring
#17: Cultural, Religious and Historical sites	High	Medium	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring
OPERATION			
#13: Land and Assets	N.A.	N.A.	Impacts are expected to be delivered during pre-construction only
#14: Occupational Health and Safety (OHS)	High	Medium	Associated plans: OHS Plan for operation Medium significance of residual impacts reinforces the need for strict implementation and monitoring
#15: Community Health and Safety	Very high	High	Associated plans: Dam Break Analysis, Emergency Preparedness and Disaster Management Plan, General Public Grievance Mechanism

IESC	Significance of the impacts		Notes
	Pre-mitigation	Post-mitigation	
			High significance of residual impacts reinforces the need for strict implementation, monitoring, and engagement with communities
#16: Infrastructures	N.A.	N.A.	Impacts are expected to be delivered during pre-construction and construction only
#17: Cultural, Religious and Historical sites	High	Medium	Associated plans: Chance Finds Procedure; Cultural Heritage Management Plan Medium significance of residual impacts reinforces the need for strict implementation and monitoring

12 Cumulative Impact Assessment

The proposed 180 MW Bunakha Hydro Power Project (BHPP) on the Wangchu River is located near village Bunakha, in Chhukha Dzong (District) in the Western Bhutan. Downstream of the BHPP, there are two existing Hydro Power projects in operation; at about 3.25 Km downstream 336 MW Chhukha Hydro Electirc Project and the 1020 MW Tala Hydro Electric Project at about 15 Km downstream. Another 570 MW Wangchhu Hydro Electric Project is under consideration from an uncertain distance downstream of BHPP. All these three are run of the river projects. Bhutan's hydropower and economic growth policies are deeply intertwined, reflecting the country's reliance on its rivers. The National Energy Policy 2025 sets a new direction for the sector: while hydropower remains the backbone of Bhutan's economy, contributing substantially to Gross Domestic Product and export revenues, the policy emphasizes diversification into solar and other renewables, modernization of the grid, and improved energy efficiency to address seasonal shortages and climate risks.

Apart from these existing and proposed Hydro Power Projects, the region will undergo several development interventions in the coming future. On the economic front, Bhutan's growth strategy has historically been hydropower led, with electricity exports to India financing infrastructure, social programs, and public services. However, the government recognizes the risks of overdependence on a single sector. Current macroeconomic policies highlight the need for structural transformation and diversification, expanding into tourism, agriculture, and digital services, to build resilience against external shocks and climate variability. Bhutan's 10X National Economic Vision is to 'build a resilient, inclusive, and sustainable economy that enhances the wellbeing of all Bhutanese, grounded in the principles of Gross National Happiness (GNH), Environmental Stewardship, and Equitable Growth". The Gross National Happiness has 4 pillars; Promotion of sustainable development, Preservation and promotion of cultural values, conservation of the natural environment and Establishment of good governance. Environmental Stewardship and Conservation of Natural Environment are the top priorities of Bhutan.

The cumulative impacts of Bhutan's hydropower expansion on the physical and biological environment are substantial when multiple dams are built sequentially along the same river system. Each dam alters river flow, traps sediment, and changes water quality, but together they create compounded effects. Successive reservoirs reduce downstream sediment transport, leading to riverbed erosion and destabilized banks. Flow regulation across several dams diminishes natural variability, weakening ecosystem resilience. Reservoirs also modify local microclimates, increase methane emissions from decomposing organic matter, and heighten risks of reservoir induced seismicity and slope instability in mountainous terrain. Importantly, the presence of multiple dams magnifies disaster potential: in extreme events, failure of one dam could cascade downstream. Thus, while hydropower supports Bhutan's economic growth, the cumulative physical impacts demand basin wide planning, coordinated reservoir management, and robust sediment and ecological flow strategies to safeguard long term environmental stability. When multiple hydropower dams are located in sequence along the same river, the cumulative impacts on the physical environment can be significant and often more complex than the sum of individual dam impacts. Apart from the dams, other developmental activities such as infrastructure, enterprises, services, etc. would also contribute to these cumulative impacts. The cumulative impacts are listed in the subsequent sub-chapters below:

12.1 Land Environment

The cumulative impacts of multiple hydropower projects on the land environment are summarized below:

Land Use Change

Reservoir inundation and infrastructure development lead to permanent conversion of forests, agricultural land, and settlements. With high sensitivity due to protected forests, biodiversity corridors, and fertile soils, the overall significance is high. Recommended mitigations include careful site selection, minimizing footprint, and compensating affected households as per the Resettlement Plan.

Soil Erosion & Stability

Repeated clearing, road construction, and slope modification across multiple projects increase erosion and landslide risks. The sensitivity is high given the fragile mountain soils and steep slopes. Mitigation measures include erosion control, slope stabilization, and vegetation cover restoration.

Habitat Fragmentation (Terrestrial)

Transmission lines, access roads, and reservoir edges fragment wildlife corridors cumulatively. Sensitivity is high due to protected forests and biodiversity corridors. Mitigations involve wildlife crossings, reforestation, route optimization, and adherence to the Biodiversity Management Plan.

Waste & Land Pollution

Construction and decommissioning waste accumulate across sites, contaminating soils and degrading land. Recommended mitigations include hazardous waste management, designated disposal sites, and land restoration.

Agricultural Land Loss

Successive reservoirs and transmission corridors reduce cultivable land and livelihoods. Sensitivity is high due to fertile valleys and community dependence. Mitigations focus on avoiding fertile land, providing fair compensation, and implementing livelihood transition programs.

Cultural & Heritage Sites

Multiple projects increase risk of cumulative loss of sacred groves, heritage landscapes, and community land. Sensitivity is high given cultural heritage and community value. Mitigation strategies include cultural mapping, rerouting, and heritage conservation.

12.2 Biological Environment

Assessment of cumulative impacts requires consideration of the interaction between the BHPP and existing as well as planned developments within the Wangchhu river basin. The Bunakha project is located within a regulated hydropower cascade system, influenced by the Chhukha Hydropower Plant (336 MW), located approximately 3.25 km downstream, the Tala Hydropower Plant (1020 MW) further downstream, and the Wangchhu Hydroelectric Project (570 MW), a peaking run-of-river scheme currently under construction downstream of Tala.

These projects collectively regulate the Wangchhu River, with Bunakha functioning as an upstream addition to an already modified hydrological regime. Other potential developments within the basin, such as mining or major land-use changes, are currently limited or not clearly defined. The upstream catchment remains predominantly forested with relatively low anthropogenic pressure, and therefore the Bunakha project is expected to operate within a relatively stable ecological and hydrological system influenced primarily by seasonal variability and long-term climate change.

Hydrological Regime and Flow Alteration:

Cumulative effects are expected to occur mainly within localized dewatered reaches, particularly during the lean season, where successive abstractions may alter the timing and distribution of river flows. The proposed downstream Wangchhu peaking project may further increase short-term flow variability.

Hydrological modelling undertaken for the BHPP confirms that flow alteration is largely confined to the approximately dewatered. Environmental flow releases, established based on monthly hydrological analysis, are designed to maintain aquatic habitat connectivity and key ecological functions throughout the year. As all projects within the cascade are non-consumptive run-of-river schemes, diverted water is returned to the Wangchhu River downstream, maintaining basin-scale flow continuity and resulting in negligible changes to total annual water availability. Accordingly, cumulative hydrological impacts are primarily associated with the temporal and spatial redistribution of river flows rather than permanent water abstraction. The incremental contribution of the BHPP to cumulative hydrological alteration within the Wangchhu cascade is therefore assessed as Low to Moderate, provided that sediment management is maintained.

Community Water Use and Resource Dependency:

Current water use by communities in Bunakha and Chanachan chiwogs is not directly dependent on the Wangchhu River. Drinking water, irrigation, and livestock needs are met through tributaries and springs such as Jililumchhu, Motolumchhu, Zanteylumchhu, Chomteykha spring, and Chanachan spring, which are located at higher elevations where settlements are situated. As a result, direct cumulative impacts on community water supply due to flow regulation in the Wangchhu are negligible, and no significant water use conflicts are anticipated. Livestock grazing in forested areas near the river do utilize Wangchhu as a water source, indicating limited indirect dependence, but this does not represent a critical vulnerability at the community level.

Wildlife Water Dependency and Riparian Ecosystems:

The Wangchhu River serves as a critical ecological lifeline for wildlife, providing drinking water, habitat, and ecological connectivity. The river and its associated riparian zones support a range of species, including mammals such as Leopard Cat, Asiatic Black Bear, Dhole, Sambar Deer, Barking Deer, and Himalayan Goral, as well as water-dependent bird species such as Great Cormorant, Plumbeous Water Redstart, and Crested Kingfisher. These riparian and floodplain habitats provide essential shelter, feeding grounds, and movement corridors. Cumulative flow reduction and hydrological alteration may result in localized decreases in water availability, modification of riparian habitats, and potential disruption to wildlife access to water sources, particularly during dry periods. In the absence of adequate mitigation, such changes could lead to increased species dispersal, localized reductions in biodiversity, and potential increases in human–wildlife conflict as animals move in search of water. However, given the maintenance of

environmental flows, continued availability of tributary water sources, and the largely intact forested landscape, these impacts are expected to remain moderate and manageable.

Aquatic Ecology and Habitat Connectivity:

Aquatic ecology within the project area is already influenced by the existing cascade system. Baseline studies indicate low fish species richness, dominated by resilient native species such as Schizothorax richardsonii, along with the presence of introduced species such as brown trout (Salmo trutta), reflecting historical ecological modification.

Cumulative Fish Passage and Connectivity:

The Wangchhu cascade comprises multiple run-of-river hydropower projects that collectively act as barriers to longitudinal fish movement. Migratory and flow-dependent species such as Tor putitora and *Schizothorax richardsonii* require seasonal upstream and downstream movement for spawning, feeding, and lifecycle completion.

Although individual projects may have a limited impact in isolation, their cumulative presence significantly reduces river permeability. A qualitative assessment of fish passage conditions is presented below:

Project	Type	Fish Passage Provision	Barrier Permeability	Cumulative Effect
Chhukha HPP	Run-of-River	Not documented	High barrier	Restricts migration
Tala HPP	Run-of-River	Not documented	High barrier	Reinforces barrier
Wangchhu HPP (under construction)	Run-of-River	To be confirmed	Likely moderate–high	Adds to the cascade
Bunakha HPP	Conventional storage	Not Required	Additional barrier	Further reduces connectivity

The cumulative effect of these structures results in a near-continuous barrier system along the Wangchhu River. Even in systems with relatively low species richness, such fragmentation can have significant ecological consequences, including restricted access to spawning grounds, population isolation, and long-term species decline.

Accordingly, the cumulative impact on aquatic connectivity is assessed as moderate at the project level but high at the basin level.

Mitigation and Management Measures

To address cumulative connectivity impacts, the following measures will be implemented:

- Assessment of fish passage feasibility during detailed design
- Optimization of environmental flow regimes to support ecological functions and seasonal migration
- Implementation of Fisheries Conservation and Management Plan (FCMP)
- Long-term monitoring of fish diversity, abundance (CPUE), and seasonal movement patterns
- Integration with basin-level biodiversity management frameworks

Transboundary Impact Assessment

The Wangchhu River flows downstream into India, where it forms part of the Brahmaputra River system after entering West Bengal. In accordance with the requirements of the Asian Development Bank Safeguard Policy Statement (2009), Appendix 1, paragraph 7, potential transboundary impacts have been considered.

Impact Pathways

Potential transboundary impacts may occur through:

- Flow regulation and alteration of natural hydrological variability
- Reduction in sediment transport due to cumulative upstream abstraction
- Changes in aquatic habitat conditions and fish populations

Transboundary Receptors

Potential receptors include:

- Downstream riverine ecosystems in West Bengal
- Aquatic biodiversity and fisheries resources
- Communities indirectly dependent on river ecosystem services

Impact Significance

Impact Type	Receptor	Significance	Justification
Flow alteration	Downstream ecosystems	Low–Moderate	RoR projects maintain flow continuity
Sediment transport	River morphology	Moderate	Cascade trapping effects
Aquatic ecology	Fish populations	Moderate	Combined barrier + flow impacts

Overall, transboundary impacts are assessed as low to moderate, given the non-consumptive nature of the project.

Stakeholder Considerations

Downstream stakeholders have been considered in line with ADB SPS requirements. Given the limited magnitude of impacts, formal cross-border stakeholder engagement is not considered necessary; however, disclosure through appropriate government channels is recommended.

Vegetation, Catchment Functions, and Water Regulation

Wild plants and forest ecosystems within the Bunakha catchment play a fundamental role in maintaining hydrological balance and ecosystem health. Native vegetation enhances infiltration, reduces surface runoff, stabilizes slopes, and supports groundwater recharge, thereby contributing to sustained river flows and water quality. These ecosystems also regulate local microclimatic conditions, including humidity and rainfall patterns. Native plant species are more efficient in water use and are therefore essential for long-term watershed stability and ecological resilience. The project's Greenbelt Management Plan and Compensatory Afforestation Plan, which prioritize native species, will help maintain these ecological functions and minimize cumulative impacts on water regulation and biodiversity.

Cumulative Sediment Dynamics

Sediment modelling undertaken for the Project indicates that the Wangchhu River continues to transport substantial suspended sediment during monsoon conditions despite regulation by existing downstream hydropower projects. The Bunakha diversion structure will retain a proportion of sediments within the intake area; however, sediment flushing facilities incorporated into the design will reduce long-term accumulation and facilitate downstream sediment transfer during high-flow events.

At the cumulative scale, sediment reduction is expected to contribute incrementally to ongoing riverbed armouring and localized channel adjustment already occurring within the regulated Wangchhu cascade.

Long-term monitoring of sediment transport, river morphology, and downstream habitat conditions shall be implemented to verify predicted impacts and support adaptive management.

Watershed-Scale Perspective

At the watershed scale, the Bunakha project represents a small incremental addition within an already regulated river basin. Water abstraction is temporary and non-consumptive, with all diverted flows re-entering the river system downstream. Competition for water use within the basin is limited, and no significant water use conflicts are anticipated. Therefore, cumulative impacts at the sub-basin and national scale are negligible and largely confined to localized ecological zones within the river corridor.

Socio-Economic and Induced Development Effects

Socio-economically, the project area is characterized by low population density and limited dependence on the Wangchhu River for direct water use. As such, cumulative impacts on livelihoods and resource use are minimal. Induced development along access roads is expected to remain limited due to existing settlement patterns and regulatory controls exercised by district authorities.

Positive Cumulative Impacts

In addition to manageable environmental impacts, the BHPP contributes positively at the cumulative level by enhancing renewable energy generation, improving cascade efficiency within the Wangchhu basin, and supporting Bhutan's low-carbon development strategy through the reduction of greenhouse gas emissions.

The cumulative impacts of the BHPP, when considered alongside existing and planned hydropower developments within the Wangchhu basin, are primarily associated with flow regulation, sediment dynamics, and ecological connectivity. While most impacts remain localized and non-consumptive, certain cumulative effects—particularly those related to fish migration barriers and aquatic connectivity- are significant at the basin scale.

In addition, potential transboundary impacts have been assessed in accordance with international safeguard requirements and are considered low to moderate. With the implementation of environmental flow regimes, biodiversity management plans, and adaptive monitoring systems, the BHPP is expected to represent a controlled and acceptable incremental addition to the existing hydropower cascade, with cumulative impacts that are manageable within a basin-wide environmental management framework.

12.3 Socio-Economic Impacts

Impact in ribbon development

It is anticipated that construction of hydropower and road will increase opportunities for people to bring their agriculture products to markets and improve to healthcare and education facilities. Hydropower construction will result in an influx of labour, which will likely generate more local business, particularly at roadside restaurants, with a possible shift from traditional sources of livelihood. However, this can also result in increased gender-based violence near these establishments and other significant impacts in less densely populated areas. An Increase in infrastructure development in the area may also increase the responsibilities for the local government including an increase in monitoring and security requirements for individual projects, and an increase in security needs for communities to manage increased influx. There is a potential that, in the medium term (5–10 years), improved transport and electricity infrastructure may result in increased migration into the basin. This could further increase the pressure on agricultural lands and non-timber forest products

Income generation and livelihood sources

Construction of Hydropower project in the Basin is expected to provide short- and long-term employment opportunities and benefits. During the construction phase, the employment opportunities is anticipated to grow which will be decrease during the operation phase. Due to influx of migrant workers, local business will boost, restaurants, hotels, agricultural products will boost in construction phase and will be decreased in operation. of local agriculture products will put pressure in food sufficiency of community. Increase in economic transaction and consumption of local foods will affected food supply and nutrition to the community people.

Impact on local governance and service delivery

Local government will have responsibility in implementing and monitoring project activities in the local context. Increases in infrastructure development may add stress to the existing human resources available within the local and district government, as they bear the responsibility for monitoring, as well as facilitating coordination between the project and the communities. There may be an increase in demand for security personnel, in addition to clearances that may be required for various purposes, e.g., the divisional forest office will be responsible for any clearances required for community forests

Impact in social cohesion and quality of life

Construction of HP projects in the basin may experience diminished social cohesion and cultural identity due to direct and induced impacts, including land acquisition and resettlement, workforce mobilization and influx of large number of workforces. The large Influx of foreign workers and in general the influx of population can have significant impacts on general security, community safety and wellbeing and social links and gender related impacts. There is a potential for these impacts to be mitigated and reversed but these impacts are expected to be exacerbated by other social changes occurring in the region, leading to a greater overall effect on the Community Quality of Life

Change in Cultural Identity

Change in settlement and urban growth will attract more population in the project area. Demographic changes in local communities generated by resettlement activities and hydropower and road development induced influx, including workforce, workforce families, and other economic opportunity seekers, will contribute to impacts on cultural identity. The influx of non-nationals will impact on the cultural fabric of the local communities in the places where they work, reside, or spend leisure time, diluting local norms and language. Local communities may see an increase in population from other communities of different ethnic backgrounds, influencing the intangible cultural resources, such as languages, and festivals. Traditional artefacts may see a decline resulting from a change in livelihood patterns and increased connectivity to markets. A decrease in E-Flow with the other hydropower projects that are future planned, and under construction may have severe impacts on access to the river for cultural purposes. Haphazard development resulting from road connectivity and population influx may impact on the traditional architecture of the place.

Impact in social capital

Changing context of population migration in the project site, the new entrant through influx, existing social safety net and cohesion may weaken or lost. Social safety nets include informal,

but established, patterns of caring for elders, impoverished, or otherwise socioeconomically vulnerable individuals who may not have the means to meet their basic needs independent of community support. This is more significant among indigenous communities, which are more communal. Communities reported relying on neighbors during health emergencies, or for financial advice, among other things. Vulnerable households without land ownership often rely on someone else's land for their livelihood (land users). Losing land access will potentially result in increased vulnerability for such households.

Impact on Gender Based Violence

Given the context of large number of workers required for the project and the influx of labor and other development activities related to the project may contribute to an increase in the risk of trafficking in persons, especially during project construction, which warrants appropriate mitigation measures to address such risks.

It is understood that personal aspirations play a major part when offenders are not from the known social circle of the victims. Juvenile and adolescent victims especially fall prey to the false promises made by strangers not only for an economically stable life, but also for exposure to different geographies, cultures, traditions, and what they believe would be a better way of life. In rural areas, Internet connectivity and smart phones have brought greater exposure, leading to new aspirations among the youth, some of whom choose to leave home. The aspiration for a better life leads some people to be trafficked, as they place their trust in unknown persons who turn out to be traffickers.

Downstream public safety

Construction of hydropower operations can pose risks to downstream public safety, particularly due to fluctuating water levels and increased flow velocities and increase flood risks. The total flood-wave arrival time from peak operations will increase, posing a significant risk to downstream communities. Proper flow management strategies are required to mitigate these impacts. In the Bunakha basin, the cumulative impacts of water level changes may lead to a major negative impact without proper safety protocols.

12.4 Minimum E-flow Impacts

The e-flow assessment undertaken for the Bunakha HPP demonstrated that a carefully designed and managed e-flow regime can maintain the ecological functionality, health and integrity of the Wangchu River while supporting the operational objectives of the proposed hydropower scheme. The e-flow assessment included hydrological analyses, hydraulic modelling, aquatic ecology surveys undertaken across three seasons, geomorphological assessments, and specialist reviews to determine the flow requirements necessary to sustain key biophysical processes and aquatic biodiversity. Particular emphasis was placed on the habitat and life-stage requirements of the indicator species S. richardsonii and flow-sensitive macroinvertebrate families.

Based on the ecological requirements of the selected aquatic biota, and to ensure the maintenance of suitable habitat conditions, ecological connectivity, migration pathways, spawning opportunities, refuge habitats, and associated ecosystem processes downstream of the proposed development, a proposed e-flow regime was developed for the Wangchu River. The recommended e-flow components and associated flow releases are presented in Table 61 below.

It should be noted that confidence in some of the hydraulic and ecological relationships underpinning the assessment was constrained by limitations in the available data, including the reliance on a single representative cross-section, limited hydraulic calibration data, the absence of detailed habitat mapping, and the lack of long-term water quality and sediment transport information. Consequently, the recommended e-flow regime should be viewed as a precautionary and scientifically defensible approach that is based on the best available information and specialist judgement.

Table 61: Summary of the final e-flows for Wanchu River at e-flow site

Component	Requirement
Reference flows, 1976-2024 (MCM)	3014.5
Total e-flows	9.54%
Base-flows	9.08%
Drought flows	1.82%
Freshets/ floods	0.46%

The above recommended e-flow regime comprised a combination of seasonal base-flows, drought protection flows, and periodic freshet releases designed to mimic key elements of the natural flow regime. The regime aims to:

- Maintain year-round aquatic habitat and ecological connectivity;
- Provide suitable hydraulic conditions for S. richardsonii migration, spawning, juvenile development, feeding, and refuge requirements;
- Sustain macroinvertebrate communities and overall aquatic ecosystem health;
- Support sediment mobilisation, channel maintenance, and habitat renewal processes; and
- Preserve water quality and ecosystem resilience throughout the annual hydrological cycle.

The study recommends that the proposed e-flow regime be implemented within Dewatered Reach 2, between the Chukha and Tala dams, to restore key ecological processes and improve aquatic habitat conditions along approximately 10 km of river reach. Although this would not fully compensate for the loss of river habitat associated with the Bunakha Dam development, it would provide a meaningful ecological offset. When combined with the proposed fish conservation and enhancement programme, these measures would contribute towards no net loss objectives for aquatic ecosystem function and indigenous fish populations at the river-system scale, while delivering a localised net gain in ecological condition within the enhanced reach.

To reduce uncertainty and improve confidence in future e-flow management, implementation of the recommended flow regime should be supported by an updated eflow study to improve on the current gaps (such as hydraulics, scenario analysis, habitat mapping, stakeholder input). The updated e-flows study should inform a comprehensive Environmental Flow Management Plan, together with long-term ecological, hydraulic, and water quality monitoring. An adaptive management framework should be adopted to evaluate ecosystem responses and refine environmental flow releases as additional ecological and operational data become available. This approach will assist in maintaining the long-term ecological integrity and resilience of the

Wangchu River while optimising the benefits of the Bunakha Hydropower Project within the broader Wangchu cascade system

As an alternative scenario to the identified recommendation of the eflow study, the specialist were requested to consider another scenario of a constant 5 m^3/s flow as an e-flow. This flow is proposed by the developer from the Bunakha Dam to the Tala Dam (Dewatered Reach 1 and 2).

This constant 5 m3/s flow is slightly higher than the average flows proposed under the variable e-flow and lacks the higher flows as freshets to stimulate and facilitate spawning and migrations.

The positive aspects of the 5 m3/s is that the reach from Bunakha to Tala will be permanently wetted with no dewatered reach.

The negative impacts that will incur should the constant 5m3/s e-flows be implemented:

- Constant habitat diversity and availability along Dewatered Reach 1 and 2;
- No seasonal flow variability that the initial e-flow regime was specifically designed around in order to maintain habitats by flushing and renewing gravel habitats unless the reservoir spills. This is likely to degrade the gravel and cobble habitat quality and embeddedness, with consequences for fish and macroinvertebrate recruitment and sustainability;
- Macroinvertebrate and food-web decline would occur, as Hptageniidae decline under reduced, non-fluctuating flow, weaking the prey base that supports Snow Trout condition and growth;
- Lack of flow related queues for fish migration and spawning;
- Reduced habitat heterogeneity resulting from a static flow regime that homogenises channel hydraulic conditions;
- Loss of juvenile refuge and marginal nursery habitats on which juvenile fish depend. A constant elevated flow regime will not create the low-velocity refuge conditions required by juveniles during genuine low-flow periods, thereby reducing the availability of suitable nursery and refuge habitat ; and
- Lack of wetting new instream habitats and riparian vegetation habitat to support biological lifecycles during the wet season.

The overall outcome of a constant 5 m^3/s flow regime is a general deterioration in aquatic habitat quality, a loss of the seasonal habitat variability that the river ecosystem and its dependent species rely on, and a resulting decline in aquatic life and biodiversity within the affected reaches. These impacts are unlikely to remain confined to the Snow Trout population itself; other flow-dependent biota, including macroinvertebrate communities and their associated food webs, would also be affected, with knock-on consequences for the broader riverine ecosystem. In turn, this has the potential to affect other biota and stakeholders that depend, directly or indirectly, on the ecological condition of the instream habitat and its associated biodiversity, including downstream ecological processes, ecosystem services, and the communities and land uses that rely on a functioning river system.

A separate E-Flow Report and Management Plan has been prepared as an annex to the ESIA. Further details can be referred to in the E-Flow Report.

12.5 Climate Change Impacts

Details in Chapter 9.

12.6 Cumulative Operational Phase Impacts

Although construction activities generate short-term cumulative disturbances, the principal cumulative effects occur during the operational life of the Wangchhu hydropower cascade.

Operational cumulative impacts include:

Hydrological Regulation

Continuous operation of multiple hydropower facilities alters the seasonal timing and variability of river flows. The addition of BHPP will marginally increase regulation within the cascade; however, compliance with environmental flow requirements will maintain minimum ecological flows within the dewatered reach.

Sediment Transport

Long-term operation of multiple diversion structures progressively modifies downstream sediment transport, potentially contributing to localized riverbed degradation and alteration of aquatic habitats. The BHPP Sediment Management Plan and periodic sediment flushing will reduce this cumulative effect.

Aquatic Habitat and Fish Connectivity

Permanent operation of sequential hydropower projects creates cumulative barriers to longitudinal fish movement. Although fish diversity in the Wangchhu River is relatively low, continued operation of multiple projects may increase habitat fragmentation over time. Long-term ecological monitoring under the Fisheries Conservation and Management Plan (Refer 13.5.7) will evaluate cumulative effects and guide adaptive management.

River Morphology

Long-term regulation of flow and sediment transport may gradually modify channel morphology, bank stability, and gravel bar development. These changes are expected to remain localized because the project maintains environmental flows and returns diverted water downstream.

Water Quality

Operational impacts on water quality are expected to be limited. Reservoir residence time is short, minimizing risks of thermal stratification, dissolved oxygen depletion, or nutrient accumulation. Routine monitoring will verify compliance with national standards.

Greenhouse Gas Emissions

Unlike large storage reservoirs, the BHPP has a relatively small impounded area and therefore negligible reservoir greenhouse gas emissions (Refer 9.1). At the cumulative scale, the hydropower cascade contributes positively to Bhutan's low-carbon development pathway by displacing fossil fuel-based electricity generation.

Community and Public Safety

Operation of multiple hydropower facilities requires coordinated emergency preparedness, flood warning systems, dam safety inspections, and emergency response procedures. These measures become increasingly important within a cascade system where operational releases from upstream projects may influence downstream facilities.

Overall, cumulative operational impacts are assessed as Low to Moderate, with aquatic connectivity and sediment transport remaining the principal long-term cumulative environmental issues requiring adaptive basin-wide management.

12.7 Climate and Disaster Risk Assessment (CDRA) into the Cumulative Impact Assessment

The CDRA undertaken for the Bunakha Hydropower Project identifies increasing temperatures, changing precipitation patterns, more frequent extreme rainfall events, glacier-related hazards, and increased flood magnitude as the principal climate-related risks affecting the Wangchhu Basin. These climate stressors have been incorporated into the cumulative impact assessment because they may amplify the environmental effects of multiple hydropower developments operating within the same river system.

Projected increases in extreme rainfall and flood events may increase sediment production, debris flows, riverbank erosion, and infrastructure vulnerability throughout the basin. Conversely, prolonged dry periods may reduce lean-season flows, increasing cumulative pressure on aquatic ecosystems within regulated river reaches. Climate-induced variability therefore has the potential to intensify cumulative hydrological alteration, sediment dynamics, aquatic habitat fragmentation, and operational constraints across the hydropower cascade.

The project has incorporated climate resilience measures, including hydrological design based on updated flood analyses, sediment management provisions, slope stabilization measures, environmental flow releases, adaptive operational procedures, and emergency preparedness planning. These measures improve resilience not only for BHPP but also contribute to reducing cumulative climate-related risks across the Wangchhu cascade.

Adaptive monitoring of river discharge, sediment transport, water quality, aquatic ecology, slope stability, and extreme weather events will enable periodic reassessment of cumulative impacts under changing climatic conditions. This adaptive management approach is consistent with international good practice and ensures that cumulative impacts remain acceptable throughout the operational life of the Project.

The cumulative impact assessment demonstrates that the BHPP represents a relatively small incremental addition to an existing hydropower cascade within the Wangchhu Basin. Quantitative hydrological and sediment transport modelling confirms that cumulative impacts are primarily associated with localized flow regulation, sediment dynamics, and aquatic connectivity rather than basin-scale reductions in water availability. Operational-phase impacts - including long-term environmental flow management, sediment transport, aquatic habitat fragmentation, dam safety, and public safety - have been incorporated into the assessment. Furthermore, findings of the CDRA have been integrated into the cumulative assessment, recognizing that future climate change may amplify cumulative hydrological, geomorphological, and ecological effects across the basin. With implementation of sediment management, biodiversity conservation measures, coordinated cascade operation, climate-resilient infrastructure design, and adaptive monitoring, the cumulative impacts of the BHPP are expected to remain acceptable and manageable within a basin-wide environmental management framework.

13 Environmental and Social Management Plan

Based on the findings of the impact assessment, measures to mitigate or compensate for potential negative environmental and social impacts associated with the Bunakha HPP are defined. The Environmental and Social Management Plan (ESMP), presented in this chapter ("**Project's ESMP**" or simply "ESMP"), provides a structured overview of the identified impacts and corresponding mitigation/prevention/compensation measures. Monitoring requirements are presented in form of a separate **Environmental and Social Monitoring Programme** (**ESMoP**). Both are organized in tabular form.

The Project's ESMP covers the following aspects:

- The environmental or social factor that is likely to be impacted
- A brief summary of the potential impact and/or likely issue
- The identified mitigation, prevention, compensation, off-set and/or enhancement actions that aim to eliminate and/or reduce the potential impact to acceptable levels
- Responsibilities for implementation.

The ESMP (including the ESMoP) is a key document that lists the requirements and details the procedures necessary for managing the significant E&S impacts expected from the proposed Project activities. This ESMP can be used as a stand-alone document during the different phases of the Project by the DGPC, the Contractors, the governmental authorities, the financers, the auditors, and other responsible parties.

This ESMP shall serve as a guidance to the pre-construction, construction, operation and decommissioning Contractors for development of **Contractors' ESMPs**, which will state how the measures defined in this ESMP, in the Environmental Approval and related permits will be implemented by them. In other words, the Contractors' ESMPs will provide more details regarding the organization and implementation of environmental, social health and safety management during the Project implementation.

The Project ESMP is set up based on the presently available technical planning data from the 2025 update of the DPR, which is presently at draft stage.

13.1 ESHS Roles and Responsibilities

The Project organization, incl. the roles and responsibilities shall consider at all times the Project´s activities under execution, the number of required workers, the extent and complexity of the works, the site location and any associated environmental, social, health and safety (ESHS) management hazards and risks.

The Contractors shall provide an organization chart of the staff team to be appointed for the rehabilitation, construction, decommissioning and operation work, including ESHS staff members. Changes in the project organization of the Contractors are not allowed without prior written approval request from the Developer.

The general roles and responsibilities of the Project parties regarding ESHS management are outlined below.

13.1.1 Project developer - BHPL

- Coordinate the Project's implementation, including the ESHS compliance
- Tender the services including ESHS compliance as an evaluation item
- Establish contracts for the services including ESHS clauses and the requirement of mandatory compliance with the ESIA, specifically this ESMP
- Review and approve the Contractor's ESMPs
- Regularly audit the works' ESHS performance; perform the respective reporting (an external auditing plan for the works can be consulted in this ESMP)
- Act upon breach of ESHS contractual clauses
- Coordinate with the responsible agencies: regularly reporting and informing of severe breaches of ESHS performance.

In addition to its overall responsibility for Project implementation, BHPL will serve as the primary coordinating agency between the Project and relevant government authorities at national, Dzongkhag, and Gewog levels.
BHPL shall coordinate closely with Dzongkhag Administrations, Gewog Administrations, the National Land Commission Secretariat, Land Record Officers, and other relevant agencies to facilitate land acquisition, land leasing, compensation and benefit-sharing arrangements, implementation of the Resettlement Plan, stakeholder engagement activities, grievance resolution, regulatory approvals, and compliance with applicable legal and administrative requirements.
BHPL will also ensure that local government authorities are consulted and informed throughout Project planning, construction, and operation to support effective implementation and management of environmental and social commitments.

Designate a responsible officer within the ESHS -specifically the Environment Officer, supported by the Social Safeguards Officer for community- facing aspects - as the focal point for institutional coordination with other Wangchhu cascade HPP operators (Chhukha HPP, Tala HPP, and Wangchhu HPP).

This role shall include:

- maintaining the inter-operator coordination protocol referenced in Section 13.5.3.1
- ensure the cascade-wide Early Warning System (Section 13.5.3.7) remains harmonised across all plants; convening periodic coordination meetings with Chhukha HPP / Tala HPP/ Wangchhu HPP operations and safety teams
- ensure the Dam Safety Emergency Preparedness Plan (D6 of DPR) is reviewed jointly with cascade operators on an annual basis.

13.1.2 Independent ESHS consultant

BHPL shall appoint a qualified Independent ESHS Consultant with relevant expertise. The appointment of this consultant is a mandatory requirement for ADB compliance and shall not be treated as discretionary.

The Independent ESHS Consultant shall be independent of BHPL's internal project implementation team and of the Contractors, and shall be responsible for:

- Reviewing the Contractors' ESMPs prior to commencement of any works on the sites, and advising ESHS on their adequacy
- Conducting regular independent ESHS site audits during all Project phases (pre-construction, construction, operation, and decommissioning) in accordance with the external auditing plan detailed in Section 14.1
- Reviewing and providing independent assessment of the Contractors' ESHS reports
- Reporting audit findings and recommendations directly to ESHS and to the ADB as the financing institution
- Identifying any deviations from the ESMP commitments and recommending corrective actions

13.1.3 Contractors

The Contractors' responsibilities are to:

- Develop the Contractors' ESMPs, which will state how the measures defined in this ESMP and in the Environmental Approval and other related permits will be implemented by each Contractor; this implies providing more details regarding the ESHS organization and implementation during the Project execution.
- Implement the works under consideration of the Contractors' ESMP and the national ESHS legislation
- Assume full responsibility for the ESHS compliance under the contract; extend this responsibility of compliance to the sub-contractors.

For the tasks above, each Contractor shall identify an ESHS team, whose composition will depend on the nature and duration of the works to be performed and on the site characteristics. The minimum required ESHS personnel is:

- Contractor's ESHS Manager:
  - prepares the Contractors' ESMPs, including the sub-management plans referred to in Chapters 13.5 of this ESMP
  - coordinates and manages all ESHS activities, including:
    - assures that all personnel (including sub-contractors) are duly informed of the requirements contained in the Contractor's ESMP, and the associated responsibilities and implication
    - assures implementation of the Contractor's ESMP in practice
    - undertakes ESHS risk assessments
    - approves permits to work
    - approves job safety analysis
    - prepares work procedures and instructions
    - ensures training and induction on ESHS issues
    - undertakes workplace inspections (an internal auditing plan for the works can be consulted in this ESMP)
    - prepares reports
    - investigates incidents and accidents.
    - stops any activities in case of emergency or significant incompliance with the permit to work or the ESHS requirements.
  - acts as main point of contact between the regulatory authorities and the Project on ESHS issues

- Contractor's ESHS Supervisor:
  - reports to the Contractor's ESHS Manager
  - is directly involved in managing and coordinating ESHS activities on-site
  - organizes ESHS trainings
  - undertakes workplace inspections (an internal auditing plan for the works can be consulted in this ESMP)

13.1.4 RP implementation consultant

The RP Implementation Consultant shall be tasked with monitoring the adequate implementation of the measures of the Resettlement Plan into practice, and reporting to ESHS and the involved (if any) financing institution. It shall also be tasked with performing the RP closure audit.

Internal Monitoring – BHPL

BHPL, through its ESHS, shall be responsible for internal monitoring of RP implementation.

This includes:

- Tracking the delivery of compensation and entitlements to all PAPs in line with the Entitlement Matrix
- Verifying that livelihood restoration and rehabilitation measures are being implemented on schedule
- Maintaining records of all compensation payments, land acquisition activities, and grievances received through the GRM
- Preparing and submitting periodic internal monitoring reports to the ADB and relevant national authorities (as applicable) at intervals defined in the RP

13.2 Compilation of the ESMP - Pre-construction Phase

Table 62: Environmental and Social Management Plan for the Pre-construction-Physical Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC#1 Air Quality			
Transportation of construction materials and heavy machinery will contribute to cumulative airshed degradation, primarily affecting workers along the Thimphu–Phuentsholing Asian Highway (AH48), where project traffic will further worsen existing exceedances of NO_2 and elevated $PM_{2.5}$ levels. During the dry season, atmospheric stagnation, and in the wet season, up-valley winds through Chanachen toward Nayakha and Lobnekha Heritage Village, will facilitate the dispersion of dust generated from quarrying, crushing, and batching plants concentrated on the right bank near Chanachen Village.	Apply Air pollution and Noise Management Plan as detailed in Section 13.5.8	Contractor	Project's Direct Impact Area
	Follow Extensive water suppression	Contractor	Quarry, crushing, batching and internal haul roads
	Strict speed limit of 20 km/h must be enforced in all village zones	Contractor	Chanachen, Bunakha, Tshimalakha
	All trucks transporting aggregate, sand, or muck must be securely covered with tarpaulins	Contractor	Continuously during works
	Orient exhaust vents, aggregate dropping points, and material stockpiles perpendicular to prevailing up-valley winds to prevent dust plumes from channelling into Nayakha and Lobnekha Heritage Village.	Contractor	Chanachen crusher site
	All project machinery and transport vehicles must undergo compulsory, documented emissions testing every six months. Vehicles noncompliance to national emission standards must be immediately banned from the site.	Contractor	Continuously during works
IESC#2 Noise			
Quarrying, crushing, and batching plants near Chanachen	Apply Air pollution and Noise Management Plan as detailed in Section 13.5.8	Contractor	Project's Direct Impact Area

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
Village, along with blasting at INRQ 3 (within 100 m proximity) and heavy vehicle movements, will generate continuous high-decibel noise exceeding the national night-time limit of 55 dBA, causing significant acoustic intrusion and community distress.	Heavy project logistics and bulk material haulage through sensitive settlement zones will be restricted	Contractor	Bunakha and Chanachen Daytime hours (06:00 to 22:00).
	crushing, batching, and material loading operations must be strictly prohibited during night-time hours (22:00 to 06:00)	Contractor	Bunakha and Chanachen
IESC#3 Water Quality			
Temporary land leasing for material laydown areas, staging yards, and storage depots introduces risks of point-source contamination from drips of hydraulic fluid, diesel, or leaching of alkalinity from cement storage, which can alter the pristine heavy-metal baseline of the soil.	Maintenance of 50-meter "No-Go Buffer Zones" around community drinking water springs	Contractor	SW-05, SW-07, SW-09, and SW-10
Runoff from cleared areas will exacerbate turbidity in the Wangchhu River, which is already highly sensitive to runoff-induced sediment. Quarrying and batching plants generate highly alkaline wastewater and present a high risk of hydrocarbon leaks. Any spills from these facilities below the farm road will wash directly into the Wangchhu River,	Installation of structural erosion controls, including interceptor drains and gabion toe walls to prevent sediment washing into Wangchhu River, immediately after vegetation clearance.	Contractor	Chanachen right bank
	Concrete wash-water must pass through a pH neutralization unit before passing through multi-stage sedimentation pits.	Contractor	Batching plants
	All fuel depots, lubricant stores, and chemical admixture areas at batching/crushing sites must be on impervious concrete flooring surrounded by bund walls capable of holding 110% of the largest tank's volume.	Contractor	Quarrying Plants
	Oil/Water separators must be installed on drainage lines	Contractor	Workshop areas

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
violating its pristine "zero-tolerance" baseline	All camps must be equipped with engineered septic systems or package Sewage Treatment Plants (STPs) located at least 50 meters away from any natural watercourse or community spring.	Contractor	Camp site
IESC#4 Soil Quality			
Soil compaction due to heavy vehicle parking destroy natural soil porosity, reduce water infiltration rates and soil quality	Apply Soil Conservation Plan as detailed in Section 13.5.11 and Land Restoration and Landscaping Plan as detailed in Section 13.5.12.	Contractor	Temporary land leasing (laydown areas, staging yards, and storage depots) and other construction sites.
	Contractor should Implement a mandatory "Topsoil Management Protocol" for all leased land.		
Prolonged staging of vehicles and storage of materials can chemically alter the pristine neutral-to-acidic pH (4.65 - 6.94) and heavy-metal baseline.	Enforce strict handling protocols for concrete admixtures, fuels, and lubricants. Refuelling of heavy machinery within 50 meters of the active river channel is prohibited.	Contractor	
	Ensure that all fuel depots, lubricant stores, and chemical admixture areas must be on impervious concrete flooring surrounded by bund walls capable of holding 110% of the largest tank's volume.	Contractor	batching/crushing sites
Loss of topsoil due to vegetation clearing	Implement a mandatory "Topsoil Management Protocol" for all leased land. Stripping of topsoil, stockpiling away from drainage paths and bounded by silt fencing	Contractor	Temporary land leasing (laydown areas, staging yards, and storage depots)

Table 63: Environmental and Social Management Plan for the Pre-construction-Biological Environment

Issue / Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #7 Protected Areas, Critical Habitat & Ecological Connectivity			
Habitat fragmentation; corridor disruption	Avoid high-sensitivity vegetation areas during final alignment and infrastructure siting; optimize footprint following mitigation hierarchy (follow 13.5.4 Biodiversity conservation & wildlife management plan)	Design Consultant	Design stage (prior to construction)
Disturbance to wildlife habitats	Integrate wildlife protection measures into contract documents and ESMP provisions (Follow 13.5.4 Biodiversity conservation & wildlife management plan). Follow the mitigation measures provided in Biodiversity Action Plan.	ESHS/Contractor	Pre-construction stage
IESC #8 Terrestrial Habitats and Fauna			
Vegetation Loss and unnecessary clearance	Demarcate vegetation clearing boundaries and restrict clearing to approved footprint	Contractor	Prior to site clearance
Improper muck disposal planning	Identify and approve muck disposal sites away from watercourses and sensitive habitats	Contractor / Design Consultant	Pre-construction stage
Permanent loss of forest land	Develop compensatory afforestation plan at minimum 1:1 ratio using native species in coordination with DoFPS and in accordance with national forestry regulations.	ESHS/ DoFPS	Pre-construction to early construction
IESC #9 Aquatic Ecology and Environmental Flow Regime			
Impact on aquatic habitats due to poor design	Incorporate erosion and sediment control measures and buffer zones in design (follow 13.5.7 Fisheries conservation and management plan)	Design Consultant	Design stage
IESC #11 Flora, Pollinators & Invasive Species			

Issue / Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
Loss of flora of conservation significance	Conduct pre-construction flora survey and implement rescue and relocation to botanical gardens in coordination with DoFPS/NBC	Contractor with DoFPS/NBC	Pre-construction

Table 64: Environmental and Social Management Plan for the Pre-construction-Human Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #13 Land and Assets			
The project is expected to cause significant direct adverse impacts, on 30 households (Land only: 29 HH and Land with Residential house: 1 HH)	Consideration of project components and facilities in minimum physical and economic displacement areas	Contractor	Project components and facilities
	Compensation at full replacement cost for structures and trees	Contractor	Continuously during works
	Livelihood restoration programs	ESHS/Contractor	Prior to construction activities
	Provide fair compensation as per Resettlement Plan as indicated in **Error! Reference source not found.** of ESIA.	ESHS/Contractor	Prior to construction activities
	Compensate affected landowners for any crop damage or property damage not resolved through corrective measures. Compensate for any damage to property caused by project-induced landslides or blasting, and provide rehabilitation assistance for affected families.	Contractor	Prior to construction activities
IESC #14 Occupational Health and Safety (OHS)			
Occupational health and safety risks arise from activities such as geotechnical investigations, construction of access roads, establishment of batching and crushing plants, workshop facilities, explosives magazine, and so on.	Contractor shall prepare CESHSMP as suggested in 13.5.19 Environment, Social, Health Safety Management Plan. Develop an Occupational Health and Safety Plan (refer 13.5.19) and Labor Management Plan (refer 13.5.9).	Contractor	Prior to construction activities
	Conduct risk assessments in line with good international industry practice to ensure worker safety	Contractor	Prior to construction activities
	Conduct induction training and implement Worker's Code of Conduct	Contractor	Prior to recruitment
	Establish Grievance Redress Mechanism to address concerns related to occupational health and safety.	Contractor	Prior to construction activities
IESC #15 Community Health and Safety			

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
The construction of access roads increases heavy vehicle movement, creating traffic hazards for pedestrians, particularly children from Chhukha Central School and patients accessing Tshimalakha Hospital located 1 - 1.2 km from the project area.	Construction activities will be carried out with 24–48 hours prior notification in coordination with local communities.	Contractor	Access road, school and Tshimalakha hospital
Generation of Dust and noise affect agricultural farm and the health of nearby residents	Preparation of Blasting Operation Plan as indicated in section 13.5.21 Blasting Operation Plan	Contractor	near Chanachen village
Risk of communicable disease transmission and social friction between workers and host communities	Strict adherence and implementation of Worker's Code of Conduct	Contractor	Camp site
Safety risks to community due to explosive magazine set up	Ensure explosives magazine to be located with 500 m setback from human occupancy	Contractor	Chanachen farm road junction (0.37 acres)
IESC #16 Infrastructures			
Transportation of equipment, supplies, and labor from India and Thimphu, significantly increases traffic on the Thimphu Phuentsholing Asian Highway and Chanachen Farm Road. Poor road conditions, lack of safety signage, and unfamiliarity of local residents with heavy vehicle increase the potential risk for accidents involving pedestrians, livestock, and other vehicles.	Develop and implement the Traffic Management Plan.	Contractor	Thimphu Phuentsholing Asian Highway, access road and Chanachen Farm Road
	Emergency Response Plans and Procedures	Contractor	Continuously in project area
	Slope stabilization must be adopted	Contractor	Very steep slope, landslide susceptible and monsoon climate

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #17 Cultural, religious and historical sites			
Indirect risks to culturally and religiously significant sites	Formulate and Train Chance Finds Procedure as part of ESMP. Chance Finds Procedure -See guidance in Culture Heritage Management Plan-Section 13.5.25.	Contractor	Religiously and culturally significant locations
	Conduct pre-construction cultural heritage baseline survey	Contractor	
	Awareness on cultural sensitivity among workers	Contractor	

13.3 Compilation of the ESMP - Construction Phase

Table 65: Environmental and Social Management Plan for the Construction-Physical Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC#1 Air Quality			
Quarry blasting and dam foundation blasting will produce dust and pulverized rock and due to up-valley winds, disperse northwards and impact Chanachen, Bunakha, Nayakha, and Lobnekha Heritage Village.	Follow Air pollution and Noise Management Plan as indicated in section 13.5.8.	Contractor	In construction phase/DIA
	Ensure Muck Transport Protocol	Contractor	
	Prior notification to local leader and restrict blasting to a narrow, fixed daytime window	Contractor	INRQ-3, 100 m from Chanachen and dam areas (24-48 hours in advance)
	Extensive water suppression using drawing water exclusively from the Wangchhu River	Contractor	Active quarry faces, internal haul roads, and the powerhouse exit
High frequency heavy truck movements significantly elevate local dust and NOx emissions along internal haul routes	Ensure that all haul trucks traveling to MD-2 and MD-4 must be securely covered with tarpaulins	Contractor	MD-2, MD-4 and internal haul routes
	Mandatory emission testing for all project machinery, transport vehicles and maintain regular servicing card.	Contractor	Every Six months
IESC #2 Noise			
The sudden shockwaves and air overpressure, amplified by the river valley due to tunnel drilling, blasting, and continuous heavy equipment operations will cause severe startle effects and intense disturbance	Prepare and follow Air pollution and Noise Management Plan as indicated in section 13.5.8 and Blasting Operation Plan as indicated in section 13.5.21.	Contractor	In construction phase/DIA
	Establishment of siren warning system and prior notification to local leader	Contractor	Chanachen and Bunakha

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
to local residents having pristine acoustic baseline (36-40 dBA).			24–48 hours in advance
	Install continuous seismographs/vibration monitor stations at critical receptor points	Contractor	Bunakha Lhakhang, the base of Lamche Bja, and the nearest houses in Chanachen
	Conduct a comprehensive structural condition (dilapidation) survey to establish a baseline for damage claims	Contractor	Every residential, commercial, and religious structure within Chanachen and Bunakha villages
Sleep disturbance due to heavy vehicle traffic on AH48, particularly at night causes sleep disturbance for residents.	Heavy project logistics and bulk material haulage through must be restricted to daytime hours	Contractor	Sensitive settlement zones (like Bunakha and Chanachen) Day time hours (06:00 to 22:00).
IESC #3 Water Quality			
Massive earthworks, excavation for the dam complex will drastically increase Total Suspended Solids (TSS), and degrading water quality	Deploy physical sediment barriers, such as turbidity curtains and settling basins to capture suspended solids	Contractor	Before water entering to the main river course.
	Maintain a continuous, ecologically calculated minimum environmental flow through the diversion tunnels at all times.	Contractor	Dewatered zone
Accidental spills of alkaline materials (cement, fly ash) or hydrocarbon leaks from heavy	Install multi-chamber sedimentation basins equipped with API oil/water separators to treat effluent. All	Contractor	Before water entering to the main river course.

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
machinery operating in the riverbed will degrade water quality	concrete wash-water must pass through a pH neutralization unit before discharge.		
Runoff from deep excavation, alkaline wastewater from concreting, and effluent from the powerhouse located at the river's edge, effluent from the access tunnel (often contains high suspended solids and traces of explosive residues) pose a direct threat to the Wangchhu River.	Site-specific Erosion and Sediment Control Plan will be implemented	Contractor	All disturbed areas
Muck disposal sites pose risks of erosion and sedimentation of downstream watercourses and leachate generation affecting water quality	Properly designed sedimentation ponds will be constructed at the toe of each primary disposal site (MD-1, MD-2, MD-4) to intercept sediment-laden runoff.	Contractor	MD-1, MD-2, MD-4
IESC #4 Soil Quality			
Chemical contamination risks from hydrocarbon leaks from heavy machinery fleets operating in the riverbed and alkaline spills from cement and fly ash used in RCC placement.	Enforce strict handling protocols for concrete admixtures, fuels, and lubricants. Secondary containment shall be provided for all fuel storage tanks.	Contractor	Powerhouse Continuously during work
Soil contamination from hazardous wastes and spills during powerhouse and transmission line construction	Conduct regular inspection of slope stability, toe walls, and drainage structures at disposal sites, especially after heavy rainfall events.	Contractor	Powerhouse and transmission line site Continuously during work
	Regularly sample downstream of disposal sites at established monitoring points (SW-2) to verify the effectiveness of sedimentation ponds.		
IESC #5 Land and Geology			
Destabilization and cumulative vibration-induced structural damage and altering landforms	Conduct regular geotechnical inspections of slopes adjacent to blast zones	Contractor	Near Chanachen and Lamche Bja
	Immediate investigation and implementation of stabilization measures (rock bolts, shotcrete, drainage) if any signs of instability	Contractor	Bunakha Lhakhang, the base of Lamche Bja, and the

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
			nearest houses in Chanachen.
Slope failure risk at nala crossing along left-bank dam access road	Construct masonry retaining walls at the nala crossing and debris-prone sections	Contractor	During access road construction
Road access disruption, traffic safety risks, slope instability, erosion, and landslides along the Phuentsholing Highway and project access roads, particularly during the monsoon season	Establish coordination among BHPL, the Contractor, and the Ministry of Infrastructure and Transport, implement slope stabilization measures, including gabion walls and masonry retaining structures, at vulnerable locations	Contractor	During access road construction
Damage to access roads and retaining structures due to rainfall, runoff, erosion, and debris accumulation	Conduct regular inspection and maintenance of roads, drainage systems, and retaining structures undertake timely debris clearance reconstruct or reinforce damaged structures as required Minimize or avoid travel along high-risk road sections during periods of intense rainfall	DGPC/Contractor	Continuously during work
IESC #6 River Morphology			
The construction program, comprising two diversion tunnels, upstream cofferdams and extensive RCC works will significantly alter the river's natural flow regime and morphology.	Physical sediment barriers, such as turbidity curtains and settling basins within the diversion channels, to capture suspended solids before water is returned to the main river course.	Contractor	Diversion tunnel, cofferdam During RCC works and before discharging into river course
The diversion will route the full 25-year flood discharge (1,822 m³/s) through the tunnels, leaving approximately 1 km of river channel, from the cofferdam to the tunnel outfall, completely dewatered	Sequence the plunge pool excavation and counter barrage construction to minimize concurrent sediment-generating activities	Contractor	below the bridge to Chanachen bridge

Table 66: Environmental and Social Management Plan for the Construction-Biological Environment

Issue / Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #7 Protected Areas, Critical Habitat & Ecological Connectivity			
Increased poaching risk	Conduct worker awareness and support DoFPS patrolling and vigilance mechanisms (follow 13.5.4 Biodiversity conservation & wildlife management plan)	Contractor	Continuous
Human–wildlife conflict	Support community-based human–wildlife conflict mitigation including awareness and reporting mechanisms	ESHS/ Contractor	During construction
Habitat fragmentation and corridor disruption	Maintain vegetation corridors and minimize clearing width	Contractor	Throughout construction
Decline of Critical Habitat species and habitats	Monitor populations of species meeting Critical Habitat criteria (Annex 7) implement Biodiversity Action Plan (BAP) adaptive management measures.	ESHS	Throughout construction
IESC #8 Terrestrial Habitats and Fauna			
Loss of vegetation and forest cover	Restrict vegetation clearing to approved footprint and implement progressive restoration; avoid unnecessary cutting (follow 13.5.4 Biodiversity conservation & wildlife management plan)	ESHS/Contractor	During construction (clearing phase)
Disturbance to mammals (e.g., *Sambar Deer*, *Himalayan Goral*)	Prohibit hunting, trapping, and wildlife harassment; conduct worker awareness programs	Contractor	Throughout construction period
Wildlife injury or displacement	Implement wildlife rescue, treatment, and release program; maintain encounter records (follow 13.5.5 Species rescue plan)	Contractor with DoFPS	As required
Disturbance to bird nesting habitats	Avoid vegetation clearing during peak breeding season where practicable	Contractor	Seasonal (breeding season)

Muck-induced habitat degradation	Controlled disposal; stabilization	Contractor	Construction
IESC #9 Aquatic Ecology and Environmental Flow Regime			
Increased sedimentation affecting aquatic biodiversity	Install erosion and sediment control measures and avoid in-river works during peak fish breeding seasons where practicable	Contractor	Throughout construction (especially during earthworks)
Fish mortality during dewatering/diversion	Conduct fish rescue and relocation during cofferdam and dewatering works using DoFPS-approved protocols and trained personnel (follow 13.5.7 Fisheries conservation and management plan)	Contractor with DoFPS	During coffer dams/dewatering
Disturbance to fish habitat (*Snow Trout*, *Brown Trout*)	Maintain environmental flow and riparian buffers to support fish migration, spawning, and habitat integrity; prohibit muck disposal in streams	Contractor	Throughout construction near water bodies
Invasive fish species introduction	Prohibit stocking of non-native species and monitor invasive aquatic species	Contractor	Throughout construction
IESC #10 Riparian and Interface Ecosystems			
Loss of riparian vegetation	Restore riverbanks using native species and bioengineering techniques (Follow 13.5.6 Greenbelt development plan)	Contractor	During and after construction
IESC #11 Flora, Pollinators & Invasive Species			
Loss of flora species (orchids, medicinal plants, etc.)	Implement flora rescue, handling, transport, and ex-situ conservation (follow 13.5.5 Species rescue plan)	Contractor with DoFPS/NBC	Prior to and during clearing
Spread of invasive species	Monitor and control invasive plant species through periodic removal programs	Contractor	Periodic during construction
IESC #12 Ecosystem Services & Functional Ecology			
Land degradation and slope instability	Implement greenbelt development for slope stabilization, muck site restoration, and landscape integration using native species	Contractor	Construction & post-construction
Loss of vegetation due to construction activities	Restore disturbed areas using native species and ecological restoration techniques	Contractor	Post-construction

Table 67: Environmental and Social Management Plan for the Construction-Human Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC#13 Land and Assets			
Acquisition of 31.38 acres of private land from 30 households will loss productive agricultural land disrupting food security and household earnings and loss the supplementary income sources.	Implementation of Resettlement Plan (RP).	Contractor	Project affected households
	Compensation at full replacement cost for residential structures, fruit-bearing trees, and other immovable assets without depreciation.	Contractor	Project affected households
	Livelihood restoration programs including training and employment opportunities for affected households.	Contractor	Project affected households
High frequency heavy truck movements significantly elevate local dust and NOx emissions along internal haul routes	Ensure that all haul trucks traveling to MD-2 and MD-4 must be securely covered with tarpaulins	Contractor	MD-2, MD-4 and internal haul routes
	Mandatory emission testing for all project machinery, transport vehicles and maintain regular servicing card.	Contractor	Every Six months
IESC #14 Occupational Health and Safety (OHS)			
Workers are exposed to working at heights, confined spaces, heavy machinery operation, and explosive materials handling.	Implement Occupational Health and Safety Plan	Contractor	Dam abutments, tunnels
	Implement Labor Management Plan	Contractor	
	Conduct periodic health and safety audits	Contractor	
	Provide medical care including treatment for injuries and any work-related illnesses, and workers who are injured should receive fair compensation	Contractor/ESHS	Continuously during work
IESC #15 Community Health and Safety			
The influx of workers (70% non-local) introduces risks of gender-based violence (GBV), sexual exploitation, abuse and harassment (SEAH), communicable diseases (STDs/STIs), and social friction with host	Prepare Labor Influx Management Plan	Contractor	In consultation with district and community leaders.

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
communities due to differing cultural norms and values.			
The presence of workers near community areas increases risks of unauthorized entry, theft, and conflict with local residents.	Strict adherence to Worker's Code of Conduct	Contractor	Continuously during work
	Restrict workers to camps during night-time hours	Contractor	Camp sites
IESC #16 Material infrastructures			
Increase traffic due to transportation of equipment, supplies	Develop and Implement Traffic Management Plan	Contractor	Thimphu-Phuentsholing Asian Highway
	Covered trucks for material transport		
	Pedestrian Plan for safe access to schools	Contractor	School areas
	Repair any damage to local roads and bridges caused by project vehicles; restore road surfaces to original condition	Contractor	Access roads
IESC #17 Emergency and Safety			
Disturbance of steep slopes and extensive use of explosives for tunnel construction could induce landslides	Closely monitor slope stability.	ADB appointed a Dam Safety Panel of Experts/Contractor	Slopes above Chanachen, cut slopes along Chanachen farm, Lamche Bja and Bunakha village
Tunnel collapse, explosion, and construction accidents pose risks to workers during tunnelling operations	Develop and implement Emergency Preparedness and Response Plan with measures for landslides, floods, tunnel collapse, and dam failure	Contractor	Tunnel areas
Dam failure during construction could cause catastrophic downstream flooding along the Wangchhu River		Contractor	affecting Chanachen, Bunakha, and Nayakha communities
IESC #18 Cultural, religious and historical site			
	Formulate Chance Finds Procedure as part of ESMP	Contractor	

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
Vulnerable to structural damage from blasting-induced vibration and dust accumulation on sacred artifacts, disrupt the spiritual atmosphere essential for worship and meditation.	Avoid blasting on auspicious religious days	Contractor	Religious structures such as temples and monasteries
	Establish spiritual foundation with Lams of Bunakha Lhakhang and Geling Goenpa; recognize sites as spiritual guardians with ceremonies from ground breaking through commissioning; support annual rituals and prayers for project safety	ESHS	Lhakhang and Geling Goenpa

13.4 Compilation of the ESMP - Operation Phase

Table 68: Environmental and Social Management Plan for the Operation-Physical Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #2 Noise Quality			
Continuous exposure of noise from turbine-generator sets; turbine hall levels can exceed 85 dBA causing occupational health hazards.	Provide adequate numbers of PPEs to workers such as ear plug in high noisy areas including powerhouse.	PSC/ESHS	Chanachen, Nayaka, Bunakha, Lobnekha Heritage, Tshimalakha, Geling Goenpa, Nayatsen and Tsho Sacred Sites
	Schedule maintenance activities during day time only and provide advance notification to communities.	PSC/ESHS	Adjacent to main access road and sacred sites due to vehicular movements
	Regular health checkup for workers during operation phase.	PSC/ESHS	Continuous throughout operation
	Provide acoustic insulation, modifying maintenance schedules, or installing silencers on equipment.	PSC/ESHS	Powerhouse
IESC #3 Water Quality			
Hazardous waste such as oils, lubricants, greases, cooling water discharge, drainage from powerhouse sumps, and sanitary wastewater during powerhouse operation may affect water quality.	Storage of all hazardous materials including used oils, lubricants and chemical wastes in bunded areas or double-walled tanks capable of holding 110% of the largest container volume to prevent spills from reaching the environment.	PSC/ ESHS	Powerhouse and transmission line

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
	Drainage from the powerhouse (including turbine pit dewatering) will pass through oil-water separators before discharge.	PSC/ ESHS	Powerhouse
	Regular inspection of critical equipment and treated through appropriate sewage treatment facilities	PSC/ ESHS	Before disposal or reuse

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #5 Land and Geology			
Peaking operation (6 hours of daily firm power generation) causes water level fluctuations, creating a drawdown zone of up to 56 m between FRL and MDDL, which may lead to bank erosion.	The rate of reservoir drawdown and refilling will be technically limited to a maximum of 2.5 m per day maintaining bank stability	PSC/ ESHS	Reservoir area
	While minimizing downstream flood impacts routed PMF (9,224 m³/s) and spillway gate operation (n-1 case) will be maintained	PSC/ ESHS	Downstream
	Reservoir Operation Manual and regular bathymetric surveys of the reservoir will be developed	PSC/ ESHS	Reservoir area
IESC #6 River Morphology			
The reservoir regulates flow below dam up to Chhukha HPP, attenuating floods and augmenting dry-season flows, which changes the hydrological character of the river downstream.	Continue e flow as per E-flow plan-for guidance see section 13.5.26. Real-time communication and operational coordination will be maintained with the downstream Chhukha HPP (336 MW) and Tala HPP (1020 MW) operators ensuring regulated releases from Bunakha.	PSC/ ESHS	River downstream

Table 69: Environmental and Social Management Plan for the Operation-Biological Environment

Issue / Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #7 Protected Areas, Critical Habitat & Ecological Connectivity			
Loss of habitat connectivity	Maintain vegetation corridors and natural habitat patches	Plant Operator	Periodic
Human Wildlife Conflict	Continue community-based human–wildlife conflict mitigation including awareness and coordination with DoFPS. Any residual human–wildlife conflict risk will be mitigated through maintenance of existing community fencing, wildlife monitoring, and implementation of community-based conflict prevention and response measures.	ESHS	Periodic
Decline of Critical Habitat species and habitats	Monitor populations of species meeting Critical Habitat criteria (Table 31 and Annex 7) through annual biodiversity surveys; implement Biodiversity Action Plan (BAP) adaptive management measures	ESHS / DoFPS / NBC	Annual biodiversity surveys throughout operation; BAP review every 3 years
IESC #8 Terrestrial Habitats and Fauna			
Disturbance to wildlife habitats near infrastructure	Conduct wildlife monitoring using camera traps, transect surveys, and opportunistic sightings	Plant Operator	Annual
IESC #9 Aquatic Ecology and Environmental Flow Regime			
Reduced downstream aquatic habitat due to altered flow	Maintain environmental flow regime reflecting seasonal variability to support fish migration, spawning, and aquatic ecosystem integrity in accordance with approved flow regime (FCMP)	Plant Operator	Continuous during operation
Changes in fish population and habitat	Implement Fisheries Conservation and Management Plan and monitor fish populations using CPUE,	Plant Operator	Bi-Annual

	species diversity, and seasonal abundance assessments		
Fish migration disruption	Monitor fish movement and migration patterns and implement adaptive management measures where required	Plant Operator	Annual
IESC #10 Riparian and Interface Ecosystems			
Degradation of riparian vegetation	Maintain and monitor riparian vegetation along riverbanks	Plant Operator	Annual
IESC #11 Flora, Pollinators & Invasive Species			
Spread of invasive plant species (Flora and Fauna)	Monitor and control invasive plant and aquatic species through periodic surveys and removal programs	Plant Operator	Annual
IESC #12 Ecosystem Services & Functional Ecology			
Poor survival of plantation areas	Monitor plantation survival and undertake replantation where required	Plant Operator	Annual

Table 70: Environmental and Social Management Plan for the Operation-Human Environment

Issue/Potential Impact	Mitigation, Prevention, Compensation and/or Enhancement Measures	Responsibility for Implementation	Timing and/or Frequency and/or Location of Implementation
IESC #13 Land and Assets			
Permanent land use restrictions for the reservoir submergence area (860.73 acres), dam footprint, powerhouse, and transmission line corridor.	Livelihood support for affected persons until their living standards are fully restored.	PSC/ ESHS	Submergence area, dam footprint, powerhouse, and transmission line corridor.
IESC #14 Occupational Health and Safety (OHS)			
The project will employ approximately 84 operational staff who will be exposed to occupational hazards including high-voltage electrical equipment (11 kV generation, 220 kV transmission line), rotating machinery (turbines and generators operating at 333.33 rpm), confined spaces (draft tube, spiral case), noise exposure (turbine hall levels exceeding 85 dBA), and fire risks from oil systems and electrical equipment.	Safety training, PPE, and emergency planning to protect workers	PSC/ ESHS	Project Operation period
	Implement Occupational Health and Safety Plan	PSC/ ESHS	
	Conduct regular safety training and drills for all 84 personnel	PSC/ ESHS	
	Provide compensation for workplace injuries Vegetation clearance along the transmission line corridor.	PSC/ ESHS	
IESC #15 Community Health and Safety			
Vehicles under construction period pose risks to pedestrians and livestock	Conduct public education and awareness meetings in local communities and local schools on reservoir safety, flow changes, and warning signals.	PSC/ ESHS	Local stakeholders
IESC #17 Emergency and Safety			
Reservoir creates a 56m drawdown zone (between FRL 2006 m and MDDL 1950m) with bank erosion and unstable slopes.	Implement Reservoir Operation Manual balancing power generation with environmental requirements	Dam Safety Panel of Experts/PSC/ ESHS	
Operation of the 205 m high dam poses risks of dam failure causing catastrophic downstream flooding.	Conduct regular dam safety inspections.	Dam Safety Panel of Experts/ ESHS	Chanachen, Bunakha, Nayakha, and all communities to Chhukha Dam (3.25 km downstream).

Rapid changes in flow during peaking operations create drowning risks in areas	Develop and implement Early warning system and Emergency evacuation plan and orientation to population residing within the proximity of impact		immediately upstream of the dam (headrace intake), and below the tailrace tunnel.
Reservoir water level fluctuations (max 2.5 m/hr) could trigger landslides on reservoir margins. Natural disasters including floods, earthquakes, and landslides continue to pose risks to communities and project infrastructure.	Conduct annual refresher public awareness meetings on reservoir safety, warning signals, and evacuation procedures.		

13.5 Sub-Management Plans

13.5.1 Catchment area treatment (CAT) plan

The Catchment Area Treatment Plan (CAT Plan) for the BHPP has been prepared to address potential impacts associated with soil erosion, slope instability, sediment generation, drainage alteration, and catchment degradation arising from project construction and operation activities. The plan is aligned with the requirements of the Asian Development Bank Safeguard Policy Statement (2009), IFC Performance Standard 6 (PS6) on Biodiversity Conservation and Sustainable Management of Living Natural Resources, the Water Act of Bhutan (2011), Forest and Nature Conservation Act and Rules of Bhutan (2023), and relevant watershed management practices applicable to hydropower development in Bhutan.

The BHPP is located within the Wangchhu River basin in western Bhutan, characterized by steep terrain, fragile slopes, high monsoonal rainfall, and environmentally sensitive mountain ecosystems. Construction activities, including excavation, slope cutting, tunneling, muck disposal, access road development, vegetation clearance, and infrastructure establishment, may increase risks of erosion, localized landslides, sedimentation, and destabilization of drainage systems if not properly managed.

The CAT Plan focuses specifically on watershed stabilization, erosion control, sediment management, and rehabilitation of environmentally sensitive catchment areas within the project influence area. The plan complements and cross-references the Biodiversity Conservation and Wildlife Management Plan (BCWMP), Compensatory Afforestation Plan (CAP), Species Rescue Plan (SRP), Greenbelt Development Plan (GDP), Fisheries Conservation and Management Plan (FCMP), Muck Disposal Management Plan, and Construction ESMP. Biodiversity conservation, compensatory plantation, species rescue, fisheries management, and greenbelt plantation measures are not duplicated under this plan and shall be implemented in accordance with their respective approved sub-plans.

13.5.1.1 Objectives

The objectives of the Catchment Area Treatment Plan are to:

- Minimize soil erosion, slope instability, and sediment transport within the project catchment area;
- Reduce sediment inflow into the Wangchhu River and downstream aquatic habitats;
- Stabilize disturbed slopes, muck disposal areas, road cuts, and exposed surfaces;
- Restore temporarily disturbed catchment areas through bioengineering and revegetation measures;
- Protect riverbanks, drainage systems, and downstream water quality;
- Enhance watershed stability and ecological resilience;
- Support long-term sustainability of environmental flow and aquatic habitat conditions; and
- Integrate structural and vegetative stabilization measures with associated biodiversity and restoration sub-plans.

13.5.1.2 Scope of the CAT Plan

The CAT Plan applies to all project components and associated areas that may contribute to erosion, sedimentation, or watershed instability, including:

- Dam and reservoir influence areas;
- Access roads and construction roads;
- Quarry and borrow areas;
- Muck disposal sites;
- Tunnel portals and adits;
- Construction camps and ancillary facilities;
- Exposed cut slopes and unstable terrain;
- Riverbanks and drainage channels;
- Temporary work areas requiring rehabilitation; and
- Downstream sections potentially affected by sediment transport.

The plan covers the pre-construction, construction, early operation, and post-construction rehabilitation phases of the project.

13.5.1.3 Policy, Legal, and Safeguard Framework

The CAT Plan has been prepared in accordance with the following national and international requirements:

- Forest and Nature Conservation Act and Rules of Bhutan (2023);
- Water Act of Bhutan (2011);
- Environmental Assessment Act and applicable regulations;
- Department of Forests and Park Services (DoFPS) watershed management and slope stabilization guidelines;
- Asian Development Bank Safeguard Policy Statement (2009);
- IFC Performance Standard 6 on Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- IFC General EHS Guidelines; and
- Good International Industry Practice (GIIP) for erosion and sediment control in hydropower projects.

13.5.1.4 Existing Catchment Conditions

The project area lies within a mountainous Himalayan catchment characterized by steep slopes, high rainfall intensity, active drainage systems, and localized slope instability. Natural conditions combined with construction activities may accelerate erosion processes if appropriate control measures are not implemented.

The catchment contains mixed forest cover, riparian vegetation, exposed rocky terrain, and localized agricultural and settlement areas. Monsoon rainfall significantly influences runoff, sediment transport, and slope stability conditions.

Sensitive receptors within the catchment include:

- Wangchhu River and tributaries;
- downstream aquatic habitats;
- riparian ecosystems;
- forested slopes;
- erosion-prone terrain; and
- community water resources.

13.5.1.5 Key Catchment Issues and Potential Impacts

Soil Erosion and Sedimentation

Excavation, vegetation clearance, road construction, muck disposal, and slope cutting may increase soil erosion and sediment transport into nearby drainage systems and river channels.

Potential impacts include:

- increased turbidity;
- sediment deposition;
- degradation of aquatic habitats;
- reduction in water quality; and
- destabilization of riverbanks.

Slope Instability and Landslide Risk

Steep terrain combined with excavation and blasting activities may increase localized risks of:

- slope failure;
- landslides;
- rockfall;
- gully erosion; and
- instability along access roads and muck disposal sites.

Drainage Alteration

Construction activities may obstruct or alter natural drainage pathways, resulting in:

- waterlogging;
- concentrated runoff;
- erosion along drainage channels; and
- downstream flooding or sedimentation.

Vegetation Loss

Temporary and permanent vegetation clearance may reduce natural slope protection and increase susceptibility to erosion and slope instability.

Compensatory plantation and ecological restoration measures shall be implemented under the Compensatory Afforestation Plan and Greenbelt Development Plan.

13.5.1.6 Catchment Treatment Strategy

The CAT strategy adopts an integrated approach combining:

- structural stabilization measures;
- drainage management;
- sediment control;
- bioengineering;
- revegetation;
- progressive rehabilitation; and
- adaptive monitoring.

Treatment measures shall prioritize:

- high-risk erosion zones;
- muck disposal areas;
- road cut slopes;
- unstable terrain;
- riverbanks; and
- disturbed catchment areas.

13.5.1.7 Catchment Treatment Measures

Bioengineering and Vegetative Stabilization

Bioengineering and vegetative stabilization measures shall be implemented to reduce erosion, stabilize exposed surfaces, and promote ecological recovery.

Measures may include:

- grass seeding and turfing;
- bamboo plantation;
- mulching;
- brush layering;
- hydroseeding;
- riparian plantation;
- live check structures;
- coir matting;
- slope plantation using deep-rooted native species; and
- progressive revegetation of disturbed surfaces.

Native and site-appropriate species shall be used in coordination with the CAP and GDP. Detailed plantation specifications, species selection, nursery requirements, and plantation monitoring are addressed under the respective plans to avoid duplication.

Structural Slope Stabilization Measures

Structural stabilization measures shall be implemented in erosion-prone and unstable areas, including:

- retaining walls;
- gabion walls;
- toe protection;
- crib walls;
- check dams;
- rock bolting and netting where necessary;
- catch drains;
- chute drains;
- contour drains;
- lined drainage channels; and
- slope benching and terracing.

Engineering measures shall be integrated with vegetative stabilization to enhance long-term slope stability.

Muck Disposal Area Stabilization

Muck disposal areas shall be designed, operated, and rehabilitated to minimize erosion and sediment generation.

Measures shall include:

- controlled muck placement;
- slope grading;
- compaction;
- toe wall protection;
- drainage diversion;
- sediment traps;
- temporary covering where required; and
- progressive rehabilitation and revegetation.

Detailed muck handling and disposal procedures are addressed under the Muck Disposal Management Plan.

Riverbank Protection and Sediment Control

Sediment and erosion control measures shall be implemented near watercourses and drainage systems to minimize sediment discharge into the Wangchhu River and tributaries.

Measures shall include:

- silt fencing;
- sedimentation ponds;
- sediment traps;
- riprap placement;
- runoff diversion channels;
- stabilized drainage outlets;
- temporary check dams; and
- controlled discharge arrangements.

Aquatic habitat protection and fisheries-specific mitigation measures shall be implemented under the Fisheries Conservation and Management Plan.

Access Road Stabilization

Road corridors shall be stabilized using:

- proper slope cutting techniques;
- retaining structures;
- drainage systems;
- cross-drainage structures;
- bioengineering measures; and
- progressive revegetation.

Roadside erosion and drainage failures shall be inspected regularly, particularly during monsoon periods.

Rehabilitation of Temporary Disturbance Areas

All temporarily disturbed areas shall be rehabilitated following completion of construction activities.

Rehabilitation measures shall include:

- removal of waste materials;
- regrading and contouring;
- topsoil replacement where feasible;
- revegetation using native species; and
- stabilization of exposed surfaces.

13.5.1.8 Integration with Other Environmental Sub-Plans

Implementation of the CAT Plan shall be closely coordinated with associated environmental sub-plans to ensure integrated environmental management and avoid duplication.

Table 71: Plans related to CAT

Related Plan	Relationship with the CAT Plan
Compensatory Afforestation Plan	Supports catchment revegetation and watershed stabilization
Biodiversity Conservation and Wildlife Management Plan	Supports habitat restoration and ecological connectivity
Species Rescue Plan	Coordinates flora and fauna rescue before site clearance
Greenbelt Development Plan	Supports stabilization and rehabilitation
Fisheries Conservation and Management Plan	Supports sediment control and aquatic habitat protection
Muck Disposal Management Plan	Coordinates stabilization and rehabilitation of muck disposal sites
Construction ESMP	Integrates erosion and sediment control requirements into construction management

13.5.1.9 Institutional Responsibilities

Table 72: Institutional responsibilities

Institution / Agency	Responsibility
BHPL	Overall implementation, funding, and compliance
EPC Contractor	Implementation of CAT measures at site level
Supervision Consultant	Monitoring, inspection, and reporting
Department of Forests and Park Services (DoFPS)	Technical guidance and oversight
Biodiversity Management Committee (BMC)	Coordination with biodiversity-related sub-plans

13.5.1.10 Monitoring and Adaptive Management

Monitoring shall be undertaken throughout construction and early operation phases to evaluate the effectiveness of catchment treatment measures.

Table 73: Monitoring Indicators

Parameter	Monitoring Indicator
Slope stability	Presence of erosion, slumping, or landslide signs
Sediment control structures	Functionality and maintenance status
Drainage systems	Unobstructed drainage flow
Rehabilitation works	Area rehabilitated
Vegetative stabilization	Vegetation establishment and survival
Riverbank condition	Bank erosion observations
Muck disposal stability	Stability of muck slopes
Sediment discharge	Visual sediment load observations

Corrective actions and adaptive measures shall be implemented where monitoring identifies ineffective stabilization or erosion control measures.

13.5.1.11 Reporting

The Contractor shall maintain records of:

- erosion incidents;
- slope failures;
- sediment control maintenance;
- rehabilitation progress;
- drainage inspections; and
- corrective actions implemented.

Monitoring results shall be incorporated into Monthly Environmental and Social Monitoring Reports and Annual Environmental Monitoring Reports.

13.5.1.12 Cost and Budgetary Provision

Costs associated with biodiversity restoration, compensatory plantation, species rescue, greenbelt plantation, and fisheries conservation are incorporated within the respective CAP, BCWMP, SRP, GDP, and FCMP budgets to avoid duplication.

The CAT Plan budget shall therefore focus on:

- structural erosion control measures;
- drainage stabilization works;
- slope stabilization structures;
- sediment control systems;
- bioengineering works not covered under CAP/GDP;
- rehabilitation support; and
- monitoring and adaptive management.

Table 74: Indicative Cost Estimate for CAT Measures

Cost Item	Estimated Cost (BTN)
Slope stabilization structures	18,000,000
Drainage and sediment control systems	10,000,000
Bioengineering and erosion control	8,000,000
Rehabilitation of disturbed areas	5,000,000
Monitoring and adaptive management	3,000,000
Contingency (10%)	4,400,000
Total Estimated CAT Plan Cost	**48,400,000**

Note: Final costs shall be updated during detailed engineering design and implementation planning.

13.5.1.13 Catchment Area Treatment Plan Implementation and Monitoring Matrix

Activity / Impact Trigger	CAT Measure	Location	Project Phase	Responsibility	Monitoring Indicator
Slope cutting and excavation	Retaining walls, benching, drainage, bioengineering	Cut slopes, roads	Construction	Contractor	Stable slopes, no major erosion
Muck disposal	Grading, toe protection, revegetation	Muck disposal sites	Construction & Post-construction	Contractor	Stabilized muck surfaces
Drainage alteration	Catch drains and diversion channels	Construction sites	Construction	Contractor	Proper drainage flow
Riverbank erosion	Riprap, riparian stabilization	Wangchhu River sections	Construction & Operation	Contractor	Riverbank stability
Exposed disturbed land	Progressive rehabilitation and revegetation	Temporary work areas	Construction & Post-construction	Contractor	Area rehabilitated
Sediment discharge	Sediment traps and silt fencing	Near watercourses	Construction	Contractor	Reduced visible sediment
Landslide-prone areas	Structural stabilization and monitoring	High-risk slopes	Construction & Operation	Contractor / PSC	No major slope failures
Access road erosion	Roadside stabilization and drainage	Access roads	Construction & Operation	Contractor	Reduced roadside erosion

The Catchment Area Treatment Plan provides a structured framework for minimizing erosion, slope instability, sedimentation, and catchment degradation associated with the BHPP. Through implementation of integrated structural, drainage, bioengineering, and rehabilitation measures, the plan will support watershed stability, protection of downstream aquatic systems, and long-term environmental sustainability.

Implementation of the CAT Plan in coordination with the Biodiversity Conservation and Wildlife Management Plan, Compensatory Afforestation Plan, Species Rescue Plan, Greenbelt Development Plan, Fisheries Conservation and Management Plan, and Construction ESMP will contribute to compliance with Bhutanese regulatory requirements, ADB SPS (2009), IFC PS6, and Good International Industry Practice for sustainable hydropower development.

13.5.2 Compensatory afforestation plan

The Compensatory Afforestation Plan (CAP) for the BHPP has been prepared in accordance with the Bhutan Guidelines on Compensatory Afforestation and the Forest and Nature Conservation Act and Rules of Bhutan, 2023 and is also aligned with the requirements of the Asian Development Bank Safeguard Policy Statement (2009) and International Finance Corporation (IFC) Performance Standard 6 (PS6) on Biodiversity Conservation and Sustainable Management of Living Natural Resources. The CAP is designed to support Bhutan's national commitment to maintaining a minimum of 60% forest cover at all times, while applying the mitigation hierarchy of avoidance, minimization, restoration, and offsetting, as required under PS6.

Construction of the BHPP will require vegetation clearance for key project components, including the dam and reservoir area, access roads, muck disposal sites, construction camps, and associated infrastructure. These activities will result in both permanent and temporary loss of forest cover and localized habitat fragmentation within the project area. Consistent with PS6 requirements for achieving no net loss of biodiversity in natural habitats, compensatory afforestation has been adopted as a key restoration and offsetting measure for unavoidable forest impacts.

In line with the Social Forestry Norms applied under major hydropower projects in Bhutan and notification, compensatory afforestation at a ratio of 1:1 (one hectare planted for every hectare of forest land affected) has been adopted for the BHPP. Based on the Land Use and Land Cover (LULC) analysis, approximately 460.233 hectares of broad leaf forest land. Accordingly, the maximum area required for compensatory afforestation is estimated at approximately 460.233 hectares. The final afforestation area shall be confirmed during the detailed design and forest clearance stage in coordination with the Department of Forests and Park Services (DoFPS).

In accordance with IFC PS6, afforestation and restoration activities shall prioritize the use of native, site-appropriate species, restoration of ecological functions, and enhancement of landscape-level connectivity. Priority shall be given to degraded forest areas, erosion-prone slopes, upper catchment areas, and locations that support wildlife movement and ecological connectivity. Implementation and monitoring of the CAP shall be undertaken in close coordination with DoFPS to ensure long-term sustainability, adaptive management, and compliance with national regulations and international good practice.

13.5.2.1 Afforestation Strategy and Species Selection

Afforestation shall be undertaken using native, site-appropriate species corresponding to local forest types, including broadleaf, mixed conifer, blue pine, fir, and riparian species. Mixed-species plantations shall be prioritized to enhance ecological resilience.

Jigme Dorji National Park in the north, Jigme Khesar Strict Nature Reserve in the west, Royal Botanical Park in the east, Biological Corridor 1 linking Jigme Dorji National Park to Jigme Khesar Strict Nature Reserve in the west and Biological Corridor 1 linking Jigme Dorji National Park to Jigme Singye Wangchuk National Park in the east fall in the 50 km radius from Bunakha HPP dam. However, these protected and conservation areas do not fall in Direct Area of Influence (AoI) up to 5 km radius from Bunakha HPP dam and Indirect Area of Influence (AoI) up to 10 km radius from Bunakha HPP dam and are not affected by the BHPP footprint.

** Only Paro Wetland is located outside the Direct Area of Influence (AoI) and falls within the Indirect Area of Influence (AoI).*

Table 75: List of plants suitable for Bunakha HPP

Sl no	Scientific name	Habit
1	*Acer campbellii*	deciduous
2	*Rhus spp*	deciduous
3	*Betula alnoides*	deciduous
4	*Carpinus viminea*	deciduous
5	*Benthamedia capitata*	evergreen
6	*Quercus oxyodon*	evergreen
7	*Quercus glauca*	evergreen
8	*Quercus lanata*	evergreen
9	*Lithocarpus fenestratus*	evergreen
10	*Dodecadenia grandiflora*	evergreen
11	*Cinnamomum glanduliferum*	evergreen
12	*Michelia doltsapa*	evergreen
13	*Pinus wallichiana*	evergreen
14	*Prunus nepalensis*	deciduous
15	*Quercus griffithii*	deciduous
16	*Syzygium cumini*	evergreen
17	*Castonopsis hystrix*	ever green
18	*Acer oblongum*	evergreen
19	*Acer sterculiaceum*	deciduous
20	*Ligustrum confussum*	Evergreen
21	*Tetradium fraxinifolium*	deciduous
22	*Corylus ferox*	deciduous
23	*Malus baccata*	deciduous

13.5.2.2 Implementation

The Territorial Forest Divisions, Parks, and the BHPP Authority shall be responsible for the planning and implementation of compensatory afforestation activities in accordance with the

Memorandum of Understanding (MoU) to be executed between the Department of Forests and Park Services (DoFPS) and the BHPL. DoFPS will hand over the compensatory afforestation activities implementation in the field to Green Bhutan Corporation Limited (GBCL). The Social Forestry and Extension Division shall serve as the focal technical agency, providing technical guidance, overseeing implementation, and undertaking need-based monitoring and evaluation from the headquarters level, while consolidating and reporting progress on afforestation activities to the BHPL in line with the EMP and ADB Safeguard Policy Statement requirements.

Afforestation activities shall commence during the pre-construction phase and continue through construction and early operation phases, including maintenance and survival replacement.

13.5.2.3 Cost Estimates

The Green Bhutan Corporation Limited (GBCL) has established and operates forest nurseries at Lamperi in Thimphu, Paro and Phuentsholing to supply native tree seedlings for hydropower and other infrastructure projects in western Bhutan. In accordance with the mitigation hierarchy and the requirements of the Asian Development Bank Safeguard Policy Statement (2009) and IFC Performance Standard 6 on Biodiversity Conservation and Sustainable Management of Living Natural Resources, the BHPP proposes to source required seedlings from these existing nurseries, subject to confirmation of species suitability, availability, and formal approval by DoFPS. On this basis, the establishment of a dedicated project-specific nursery is not envisaged at this stage.

Table 76: Expected Cost for Afforestation

Summary of Cost Estimate — Compensatory Afforestation, Bunakha HPP

Total Plantation Area: 460.233 Ha (Revised area) | Forest type: Broadleaf | Spacing: 2.5m x 2.5m | No markup/contingency applied (base costs only)

SN	Component	Particulars	Total Amount (Nu.)
1	Initial Plantation Creation (Part I-VII)	cost	79,577,150.09
2	Same Year Maintenance	Same Year Maintenance	13,731,955.09
3	1st Year Maintenance	1st Year Maintenance	24,457,836.75
4	2nd Year Maintenance	2nd Year Maintenance	21,548,794.23
5	3rd Year Maintenance	3rd Year Maintenance	18,621751.71
6	4th Year Maintenance	4th Year Maintenance	16,456,374.97
Sub total			174,411,862.85
Contengency 10%			17,441,186.28
GRAND TOTAL — Compensatory Afforestation Cost Estimate			191,853,049.13
Cost per Ha (Total Area 460.233 Ha)			381,035.03

13.5.2.4 Monitoring and Reporting

Monitoring shall be a key component in assessing the effectiveness and success of plantation and site rehabilitation works under the BHPP. A three-tier monitoring mechanism shall be adopted, comprising: (i) regular monitoring by the implementing forestry units; (ii) ad hoc monitoring by the Department of Forests and Park Services (DoFPS); and (iii) joint monitoring by the implementing agencies, DoFPS, and the BHPP Authority. Detailed monitoring protocols, indicators, and reporting arrangements shall be defined in the Memorandum of Understanding (MoU). The Social Forestry and Extension Division shall submit bi-annual progress reports and an annual consolidated report on the status of compensatory afforestation to the BHPP Authority. At the end of each year, DoFPS and the BHPL shall jointly review the progress of the program and, where necessary, identify and implement corrective, adaptive, or additional measures to enhance the effectiveness of the compensatory afforestation program.

This Compensatory Afforestation Plan will offset forest loss, enhance watershed stability, restore habitats, and contribute to Bhutan's national forest cover commitment.

Table 77: Compensatory Afforestation Plan

Activity / Impact Trigger	Afforestation / Plantation Measures	Location	Implementation Period	Responsibility	Monitoring Indicators	Remarks
Permanent forest land loss (dam, reservoir, access roads, camps)	Compensatory plantation at 1:1 ratio using native species	DoFPS-approved plantation areas outside the project footprint	Pre-construction to early construction	EPC Contractor / DoFPS	No. of saplings planted; plantation area (ha)	As per the Bhutan Forest & Nature Conservation Rules
Temporary vegetation clearance	Progressive re-vegetation with native grasses and shrubs	Construction sites, access roads, camps	Construction and site restoration phase	EPC Contractor	Area rehabilitated; visual inspections	Integrated with site restoration
Slope cutting and muck disposal	Bio-engineering, terracing, and deep-rooted species plantation	Cut slopes and muck disposal areas	Construction and post-construction	EPC Contractor / PSC	Slope stability; plant survival rate	To prevent erosion and landslides
Riparian vegetation loss	Riparian buffer plantation with moisture-loving native species	Wangchhu River and tributaries	Construction to early operation	EPC Contractor / DoFPS	Riparian cover; bank stability	Avoid invasive species
Wildlife habitat disturbance	Habitat connectivity-focused mixed plantation	Adjacent forest patches and restoration zones	Construction and operation	EPC Contractor / DoFPS	Natural regeneration signs; wildlife use	Linked with BMP
Visual impacts of infrastructure	Landscaping with native ornamental and shade trees	Powerhouse, colony, admin areas	Late construction and operation	EPC Contractor	Visual integration assessment	Aesthetic enhancement

Activity / Impact Trigger	Afforestation / Plantation Measures	Location	Implementation Period	Responsibility	Monitoring Indicators	Remarks
Post-construction restoration	Final recontouring and replacement planting	All temporary project areas	Post-construction	EPC Contractor	Survival rate ≥80%	Handover condition

13.5.3 Dam Safety Emergency Preparedness Plan

This Emergency Preparedness Plan (EPP) is developed for Bunakha Dam of the Wangchu river entails the following:

- organization and coordination of the responsibilities of all parties involved in managing and responding to an incident or emergency situation
- actions to be taken by the dam owner to minimize or alleviate a problem at a dam
- actions the dam owner should take, in coordination with emergency management authorities, to respond to incidents or emergency situations at a dam, evacuate personnel within or outside the site where necessary and to rehabilitate them
- presentation of procedures and information to assist the dam owner in issuing early warnings and notifications to responsible local and state authorities; inundation maps to help the dam owner and emergency management authorities with identification of critical infrastructure and sites where population is at risk;
- subsequently, identification of potential requirements for protective measures, warning and evacuation planning; and
- restoring normalcy in site operation with minimum loss of time.

A coordinated and effective response to a dam emergency requires the dam owner, local and state authorities, emergency management authorities and residents to work closely together with clearly defined responsibilities.

13.5.3.1 General Responsibilities

Owner and Operator (DGPC)

Druk Green Power Corporation Limited (DGPC), who is also the Project implementer is responsible for all dam operation and maintenance.

The operation of the dam during the operation phase will be overseen by a Head of Plant (HoP). The HoP shall be responsible for:

- initiating the implementation of the EPP.
- collecting weather forecasts and the inflow forecasts and alerting of any potential emergency situation.
- conducting routine dam maintenance, such as annual weed control, conducting dam integrity inspections, checking monitoring data, checking alarm systems, and *reservoir rim assessment*, and notifying authorities of any potential emergency situations.
- contacting emergency personnel should a dam failure be imminent.
- updating the EPP
- an annual EPP review shall be conducted to ensure that contact names and numbers are current on the Notification Flowcharts.
- directing specific, incident appropriate actions during an emergency, such as opening or closing water outlets and remedial construction activities such as earthmoving etc.

Government Agencies (Dzongkhag Disaster Management System- Chhukha Dzongkhag)

Every Dzongkhag has their Dzongkhag Disaster Management & Contingency Plans (DDMCP) with respective incident command system and responsibility matrix. All the project components fall under Chhukha Dzongkhag. There will be synergy in interfacing the project's EPP with their DDMCP for emergencies.

Government officials who are member of the Dzongkhag Disaster Management Committee are responsible for:

- Proper functioning of Dzongkhag Emergency Operation Centre.
- Mainstreaming of disaster risk (from the project) reduction into the development plan, policy and program.
- Coordinate and support disaster response in coordination with the project implementer during response and relief operation.
- With the support from BHPL, promote advocacy, awareness, capacity building and community training on hazard and risk of the BHPP.
- Establish a proper communication channel for warning in coordination with the Project owner (DGPC).

Chhukha, Tala and Wangchu Hydropower Plants

The Wangchhu River emplaces a cascade of several hydropower schemes, including the 336 MW Chuckha HPP and 1020 MW Tala HPP under operation, consisting of conventional RoR schemes with daily ponds, and the 570 MW Wangchu HPP, also RoR scheme but under development stage.

Bunackha HPP is the uppermost project, hence the storage reservoir capacity provided is expected to provide additional benefits in terms of flow regulation to the further downstream existing and planned projects. Since downstream impacts from Bunakha HPP are going to happen at the same basin, the EPP has to be administered in close coordination with Chhkha HPP, Tala HPP and future Wangchhu HPP operation teams. Moreover, any dam break emergency situation, or emergency reservoir drawdown, at the Bunakha HPP would directly impact downstream power plants.

Therefore, the administration of Chhkha HPP, Tala HPP and Wangchhu HPP will be in coordination with BHP and will be responsible for:

- Coordination of regulating water flow from the dam.
- Proper communication in case of emergency from upstream dam.
- Implementation of EAP/EPP of CHP, THP, WHP and BHP in case of emergency.

Inter-operator Coordination Protocol

Given that DGPC is the operating entity for Bunakha, Chhukha, and Tala HPPs, this protocol shall be established as a binding internal operational procedure within DGPC's project management structure.

The protocol shall govern at minimum:

- Real-time communication of reservoir levels, flow release decisions, and peaking schedule changes between plant operations teams on a daily basis and in real time during abnormal conditions
- Notification timing and procedures for emergency reservoir drawdown events, with defined lead times for downstream plant operators
- Coordinated flood management procedures during extreme precipitation or inflow events affecting the cascade simultaneously
- Annual joint review of each plant's EAP and EPP for cascade consistency, to be conducted by the Head of Plant of each facility under BHPLcoordination
- Designated focal point officers at each plant responsible for inter-operator liaison, listed in the Notification Flowchart (see Section 13.5.3.2)

The ESHS within BHPL shall be responsible for initiating, maintaining, and annually reviewing this inter-operator coordination protocol, as defined in Section 13.1.1.

To give operational effect to this coordination protocol, BHPL shall establish a formal Institutional Agreement for Cascade Emergency Coordination prior to commissioning of BHPP.

This agreement shall be executed as a binding internal BHPLoperational directive, given that DGPC is the operating entity for BHPP, Chhukha HPP, and Tala HPP. Upon commissioning of Wangchhu HPP, the agreement shall be extended to include the WHP operations team.

13.5.3.2 Responsibilities for Evacuation for downstream

The Chhukha Dzongkhag Disaster Management Committee and local Chief of Police or his representative are responsible for initiating evacuations downstream of the dam. The Emergency Response Team of Chhukha HPP, Tala HPP and Wangchhu HPPP will be responsible for the evacuation of the occupants and workers of the respective HPPs.

Communications

The DMC and local officials and downstream residents will be notified by Bhunakha HPP through by landline telephone/cell phones. Any other type of communication like SMS, email alerts and Public Announcements through PA-System shall be add-on only.

The various networks for emergency use include the networks of the following:

- Dzongkhag Tsogdu Secretary, Chhukha (Disaster focal person)
- Superintending (Chief of) Police or Officer in Charge
- The disaster focal person or Chief Security Officer of CHP, THP and WHP

Verification or authentication of the situation can be made by contacting Chief Security Officer, HoP of Bunakha HPP and Dzongkhag disaster management officials.

Television, Radio and bulk SMS facilities of the local mobile network operators shall be used as much as possible to notify area residents of the possible dangers. Public announcements are to be issued by Dzongkhag officials and Chief Security Officers of the downstream HPPs.

International coordination

Dam-related incidents at the Bunakha (Punakha) Dam on the Wangchu River have the potential to affect downstream infrastructure, settlements, and exposed areas within the Kingdom of Bhutan and, subsequently, the Republic of India and the People's Republic of Bangladesh. As no joint emergency preparedness or response mechanism currently exists between Bhutan, India, and Bangladesh for the Wangchu River basin, the relevant local and national authorities in each country must be identified and engaged separately.

While emergency action planning (EAP) discussions and coordination may be feasible at the national level within Bhutan, systematic coordination with downstream authorities in India and Bangladesh has not yet been formally established. Therefore, it is strongly recommended to continue efforts to initiate communication and coordination with the responsible disaster management and civil protection authorities in India and Bangladesh, who are accountable for issuing warnings and conducting public evacuations. Such coordination would provide critical opportunities to clarify individual and shared responsibilities and to address essential emergency planning issues, including notification protocols for public officials, the use of backup personnel, alternative communication channels, and specific procedures for nighttime events, holidays, and weekends.

Internal Responsibilities

The dam owner is responsible for maintaining a safe dam, which includes management of its operation, maintenance, repair, and rehabilitation. The dam owner operates the dam and has first-hand information about the status of the dam; and he is the first party that receives information of a pending emergency.

Additionally, in an emergency the dam owner is responsible for monitoring, early warning, determining appropriate levels of incident severity, making internal and external notifications, implementing response and mitigation actions at the dam, determining when an emergency situation no longer exists, and documenting all activities.

13.5.3.3 Emergency Management Group / Response Team

During an emergency situation, an Emergency Management Group (EMG) is a specialized group of individuals equipped with the skills and training to swiftly and effectively manage and respond to various crises, disasters, and critical incidents. Comprising professionals from diverse backgrounds such as engineering, medical, rescue, communication, logistics, and coordination, an EMG is dedicated to ensuring the safety, well-being, and recovery of affected individuals and communities during emergencies. This team is adept at assessing situations, coordinating resources, executing strategic plans, and providing immediate assistance to mitigate the impact of emergencies and restore normalcy. The EMG Response-Team's proactive and organized approach plays a vital role in minimizing risks, facilitating rapid response, and fostering resilience in the face of unexpected events.

13.5.3.4 Emergency Situations

Numerous circumstances surrounding a dam can escalate into emergency scenarios, some of which may not immediately necessitate the activation of the Emergency Action Plan (EAP). However, in the event of any of these situations, prompt and appropriate measures must be taken:

- Severe Weather Events: While severe storms and adverse weather conditions like GLOFs may not pose an immediate threat to the dam itself, they can exacerbate existing issues and impede efforts to address them. Additionally, they may lead to uncontrolled floodwater release due to a dambreak, or to an emergency reservoir drawdown with heightened flow in already saturated areas.
- Earthquakes: Situated in a high seismic activity area, Bunakha Dam faces the possibility of earthquakes. Accordingly, post-earthquake inspections should be conducted to assess any potential damage in the dam.
- Reservoir rim stability: Landslides may be triggered by extreme precipitation (cloud bursts) or strong earthquakes causing failure of the terrain at the proximity of the reservoir. Wave loading generated by a landslide entering a reservoir can induce rapid water level fluctuations, high impact pressures, and wave run-up that may trigger overtopping risks and uncontrolled flow releases.
- Sabotage: In the event of threats aimed at damaging the dam, appropriate measures should be taken to safeguard its integrity.
- Sediment Flushing: Sediment flushing can lead to release large amount of flow with high sediment concentrations, flooding downstream and potentially damaging both infrastructure and ecosystems.
- Fire Incident/Hazards: Sudden fire start within the hydropower plant premises, including generating areas, electrical panels, and storage spaces of flammable liquid & gases.

13.5.3.5 Emergency Actions for DGPC staff on duty at dam

Event	Description of situation	Emergency Level	Action to be taken
SPILLWAY FLOW	Main spillway is flowing with no active erosion. Reservoir water surface below 100 years flood level.	Non-failure	3. Check for signs of erosion from spillway channel, particularly near wing walls. 4. Assess cause of increased reservoir stage, especially during fair weather conditions. 5. Perform additional tasks as directed by Dam Engineer. 6. Make notifications according to flowchart if condition worsens.
	Spillway flow that could result in flood of people downstream if the reservoir level continues to rise Reservoir level greater than 100 years flood and is rising at a rate greater than 10 cm per hour.	Non-failure	

Event	Description of situation	Emergency Level	Action to be taken
	Spillway flowing with active erosion	Potential failure	7. Check for signs of erosion from spillway channel, particularly near wing walls. Take photos. Document location on a site plan and in inspection report. 8. Assess cause of increased reservoir stage, especially during fair weather conditions. 9. Estimate inflow using charts. 10. Lower reservoir level: Open Mid Level Outlets 11. Restrict traffic on dam crest to essential emergency operations only 12. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. 13. Make notifications according to flowchart if condition worsens.
	Spillway flowing with an advancing headcut / erosion that is threatening the control section	Imminent failure	14. Trigger Water Alarm System for immediate evacuation of downstream population. 15. Make notifications according to flowchart. 16. Lower reservoir level: Open Mid and Bottom Outlets 17. Restrict traffic on dam crest to essential emergency operations only 18. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 19. Perform additional tasks as directed by HoP.

Event	Description of situation	Emergency Level	Action to be taken
DAM OVERTOPPING	Water level in reservoir is higher than maximum operation level Reservoir level is above 2006.00 masl	Non-failure	20. Check for signs of cracking/seepage on downstream face of the dam. 21. Assess cause of increased reservoir stage, especially during fair weather conditions. 22. Estimate inflow using charts. 23. Perform additional tasks as directed by HoP. 24. Make notifications according to flowchart if condition worsens.
	Water level in reservoir is two meters below dam crest Reservoir water surface above 2008.00 masl	Potential failure	25. Check for signs of cracking/seepage on downstream face of the dam. Take photos. Document location on a site plan and in inspection report. 26. Assess cause of increased reservoir stage, especially during fair weather conditions. 27. Estimate inflow using charts. 28. Lower reservoir level: Open Spillway, Mid Level Outlets. 29. Perform additional tasks as directed by HoP. 30. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. 31. Restrict traffic on dam crest to essential emergency operations only 32. Make notifications according to flowchart if condition worsens.
	Water from the reservoir is flowing over the top of the dam Reservoir water surface above 2010.00 masl	Imminent failure	33. Trigger Water Alarm System for immediate evacuation of downstream population. 34. Make notifications according to flowchart. 35. Lower reservoir level: Open Spillway, Mid-Level and Bottom Level Outlets.

Event	Description of situation	Emergency Level	Action to be taken
			36. Restrict traffic on the dam crest to essential emergency operations only. 37. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 38. Perform additional tasks as directed by HoP.
SEEPAGE	New seepage or boil(s) observed along downstream face, toe of dam. abutments, foundation and/or drainage galleries Visual checking	Non-failure	39. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos. Document location on a site plan and in inspection report. 40. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 41. Contact the HoP and provide all data collected. 42. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. Recommend remedial seepage and stability measures. 43. Perform additional tasks as directed by the Dam Engineer 44. Make notifications according to flowchart if condition worsens.

Event	Description of situation	Emergency Level	Action to be taken
	New seepage or boil(s) observed along downstream face, toe of dam. abutments, foundation and/or drainage galleries; with increasing but controllable discharge Cumulative Flow at V notch greater than 300 l/s and increasing but less than 1300 l/s	Potential failure	45. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photos. Document location on a site plan and in inspection report. 46. Attempt to contain flow in such a manner (without performing any excavations) that flow rates can be measured, by placing a ring of sand bags if V notch is overflowing. Stockpile gravel and sand fill for later use, if necessary. 47. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 48. Contact Dam Engineer and provide all data collected. 49. Lower reservoir level below the seepage zone or as low as possible below normal level. 50. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. Recommend remedial seepage and stability measures. 51. Restrict traffic on dam crest to essential emergency operations only (use alternative way to come to the dam). 52. Perform additional tasks as directed by the Dam Engineer 53. Make notifications according to flowchart if condition worsens.

Event	Description of situation	Emergency Level	Action to be taken
	New seepage or boil(s) observed along downstream face, toe of dam. abutments, foundation and/or drainage galleries; with muddy discharge and increasing discharge of water. Visual checking, flow at V notch greater than 1300 l/s	Imminent failure	54. Trigger Water Alarm System for immediate evacuation of downstream population. 55. Make notifications according to flowchart. 56. Lower reservoir level below the seepage zone or as low as possible below normal level. 57. Restrict traffic on dam crest to essential emergency operations only. 58. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 59. Perform additional tasks as directed by the HoP.

Event	Description of situation	Emergency Level	Action to be taken
CRACKS	New longitudinal (along the dam body) or transverse (across the dam body) cracks Visual checking and local measurement: more than 15 cm deep or more than 5 cm wide or increasing with time. New concave cracks on or near the dam crest associated with high deformations.	Potential failure	60. Measure and record feature dimensions, approximate flow rate, and relative location to existing surface features. Take photo. Document location on a site plan and in an inspection report. 61. Contact the Dam Engineer and provide all data collected. 62. Place buttress fill (min 1 meter high, 5 meters wide) against base of slope immediately below surface feature and extending 15 meters beyond visible feature limits (parallel to the embankment). Stockpile additional fill. 63. Place sand bags as necessary around crack area to divert any storm water runoff from flowing into crack(s). 64. Lower reservoir level below the cracks (if possible, otherwise as low as possible). 65. Inspect the dam; collect piezometer and water level data twice daily unless otherwise instructed by the Dam Engineer; and record any changes of condition. Carefully observe the dam for signs of depressions, seepage, sinkholes, cracking or movement. 66. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. 67. If cracks extend to the crest, restrict traffic on dam crest to essential emergency operations only. 68. Make notifications according to flowchart if condition worsens.

Event	Description of situation	Emergency Level	Action to be taken
DAM MOVEMENT	Visual movement/slippage of the abutments, dam body and appurtenant structures Visual checking/Drone	Potential failure	69. Check for signs of seepage on downstream face of the dam. Take photos. Document location on a site plan and in inspection report. 70. Lower reservoir level below movement level. Open Low and Mid Level Outlets. 71. Contact HoP and provide all data collected. 72. Perform additional tasks as directed by HoP. 73. Inspect the dam; collect piezometer and water level data daily unless otherwise instructed by engineer; and record any changes of condition. Carefully observe dam for signs of depressions, seepage, sinkholes, cracking or movement. 74. Review information collected by field inspectors and provide additional instructions / actions as required. 75. Restrict traffic on dam crest to essential emergency operations only. 76. Make notifications according to flowchart if condition worsens.
	Sudden or rapidly proceeding movement of the abutments, dam body and/or appurtenant structures Visual checking/Drone	Imminent failure	77. HoP and EMG-Leader in conjunction to Trigger the Water Alarm System for immediate evacuation of downstream population. 78. Make notifications according to flowchart. 79. Lower reservoir level as soon as possible to the minimum level. 80. Restrict traffic on dam crest to essential emergency operations only.

Event	Description of situation	Emergency Level	Action to be taken
			81. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 82. Perform additional tasks as directed by HoP.
EARTHQUAKE	Measurable earthquake felt or reported on or within 50 km of the dam . No visible damage to the dam 1. reported by local authorities, local inhabitants or felt at dam site. Strong Motion Accelerometers at the dam with value greater than the 475-Year Earthquake of 0.31g i.e.: 3.0 m/s² Visual checking to be done	Non-failure	83. Make notifications according to flowchart. 84. Restrict traffic on dam crest to essential emergency operations only. 85. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Reinforced monitoring just after the earthquake. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 86. Perform additional tasks as directed by HoP.
	Earthquake resulted in visible damage to the dam or appurtenances Visual checking Strong Motion Accelerometers value at the dam greater than the 2475-Year Earthquake value of 0.49g or i.e.: 4.8 m/s²	Potential failure	87. Trigger Emergency Alarm System for immediate evacuation of downstream population. 88. Make notifications according to flowchart. 89. Lower reservoir level as soon as possible to the Minimum Operating Level. 90. Restrict traffic on dam crest to essential emergency operations only before complete inspection and new stability checking. 91. Assess extent of damage and visually inspect entire dam for additional less obvious damage.

Event	Description of situation	Emergency Level	Action to be taken
			Reinforced monitoring to detect any non reversible behavior (water pressure increase, settlements). Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 92. Perform additional tasks as directed by HoP.
	Earthquake resulted in uncontrolled release of water from the dam or significant damage observed (cracks, settlements) Visual checking	Imminent failure	93. HoP and EMG-Leader in conjunction to Trigger Emergency Alarm System for immediate evacuation of downstream population. 94. Make notifications according to flowchart. 95. Lower reservoir level as soon as possible to the minimum level. 96. Restrict traffic on dam crest to essential emergency operations only (use alternative way to come to the dam). 97. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 98. Perform additional tasks as directed by HoP.
SECURITY THREAT	Verified bomb threat that, if carried out, could result in damage to the dam Contact Local Police	Non-failure	99. Call local police, and inform them about the situation. 100. Do not approach closer than 100 m to the bomb. 101. If not getting too close to the bomb, restrict traffic on dam crest to essential emergency operations only.

Event	Description of situation	Emergency Level	Action to be taken
			102. Perform additional tasks as directed by the Police. 103. Make notifications according to flowchart if condition worsens. 104. If there is a bomb, neutralize it and remove it with bomb removal personnel of the police.
	Detonated bomb that has resulted in **severe** damage to the dam or appurtenances Contact local police and visual checking	Imminent failure	105. HoP and EMG-Leader in conjunction to Trigger Emergency Alarm System for immediate evacuation of downstream population. 106. Make notifications according to flowchart. 107. Lower reservoir level as soon as possible to the minimal level. 108. Restrict traffic on dam crest to essential emergency operations only. 109. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 110. Perform additional tasks as directed by HoP.
SABOTAGE/ VANDALISM	Damage that could adversely impact the functioning of the dam Visual checking	Non-failure	111. Measure and record damages, approximate flow rate (if relevant), and relative location to existing surface features. Take photos. Document location on a site plan and in inspection report. 112. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications.

Event	Description of situation	Emergency Level	Action to be taken
			113. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. Recommend remedial and stability measures. 114. Perform additional tasks as directed by the HoP. 115. Make notifications according to flowchart if condition worsens.
	Damage that has resulted in increased but controlled seepage flow Visual checking, flow greater than 300 l/s and increasing but less than 1300 l/s	Potential failure	116. Measure and record damages, approximate flow rate, and relative location to existing surface features. Take photos. Document location on a site plan and in inspection report. 117. Restrict traffic on dam crest to essential emergency operations only (use alternative way to come to the dam). 118. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 119. Maintain monitoring, review information collected by field inspection and provide additional instructions / actions as required. Recommend remedial and stability measures. 120. Perform additional tasks as directed by the HoP. 121. Make notifications according to flowchart if condition worsens.

Event	Description of situation	Emergency Level	Action to be taken
	Damage that has resulted in uncontrolled water release Visual checking	Imminent failure	122. Trigger Emergency Alarm System for immediate evacuation of downstream population. 123. Make notifications according to flowchart. 124. Lower reservoir level as soon as possible to the minimal level. 125. Restrict traffic on dam crest to essential emergency operations only. 126. Assess extent of damage and visually inspect entire dam for additional less obvious damage. Based on inspection results, confirm if extent of damage to various components of the dam warrants revised emergency level and additional notifications. 127. Perform additional tasks as directed by HoP.

13.5.3.6 Training and Awareness Raising

Regular training sessions and drills are essential to ensure thorough familiarity with all aspects of the Emergency Preparedness Plan and the associated duties and obligations of those involved. An adequate number of individuals should undergo training to ensure sufficient coverage at all times.

Table 78: Schedule for training and awareness raising

Exercise/Submittal	Schedule	Reporting deadline
Seminar	Annual – except during the year of a tabletop, functional, or full-scale exercise.	Submit information in EPP Status Report.
Drill – training exercise	Annual – except during the year of tabletop, functional, or full-scale exercise.	Submit information in EPP Status Report.
Tabletop Exercise	At least 30 days before comprehensive exercises	EMG Team Leader to Submit Plan & Schedule at least 90 days before exercise. Submit Evaluation Report within 60 days following exercise.

Exercise/Submittal	Schedule	Reporting deadline
Functional/Full-Scale Exercise (Comprehensive Exercise)	Every 5 years	DDMC-Chhukha to Submit Plan & Schedule at least 90 days before exercise to the EMG-Team Leader. Submit Evaluation Report within 60 days following exercise.
EPP Reprint	Every 5 years	Submit to all stakeholders.
EPP Status Report	Annual	December 31.
EPP Revisions	Varies	Submit revisions for significant discrepancies within 30 days of notification. Otherwise, submit revisions as the annual update with EPP Status Report.
Notification	Following any activation of the EPP.	Provide oral report as soon as practicable after incident occurs. Submit written report.

13.5.3.7 Early Warning System

An Early Warning System (EWS) is crucial for saving lives and livelihoods during emergencies. It involves raising awareness about risks and sharing information with vulnerable communities before disasters occur. Key elements of an EWS include understanding and mapping hazards, monitoring and predicting events, delivering clear alerts, and implementing timely responses. Engaging with vulnerable populations to understand their needs and capacities is essential. This involves community meetings, risk mapping, developing response plans, creating tailored public information, and establishing oversight mechanisms. Training and simulations are provided to ensure effective alert interpretation and response.

In case an incident is anticipated, is imminent, or has occurred, an audio signal warns the population for immediate evacuation to heights around their houses or place of work.

The proposed audio signal is a “fog horn” siren, as well as a spoken announcement based on emergency level categories.

The fog horn signal is broadcast with sirens in all villages potentially affected by the risk of dam break. Spoken announcements are delivered using the same system to inform population on the risk level and evacuation if needed.

Emergency Alarm Sirens

Characteristics of the sirens are the following:

- Range of audible sound outside and inside of buildings of 2 km in 360°. It should be sufficient to cover all inhabited areas according to the inundation maps
- 48 to 72 hours backup battery in case of electricity shortage
- Radio connection of each siren
- Remote control
- Monitoring at dam site
- Type of sound is a loud low pitched sound, typically a “fog horn”.

Emergency level categories	Fog horn siren	Spoken announcements
Exercise	Exercise signal	Exercise message
Non failure	No signal	No message
Potential failure	Alert signal	Potential failure message
Imminent failure	Alert signal	Imminent failure message

The sound of the siren is the following:

2 seconds of sound followed by 3 seconds of silence for 2 minutes.

Cycles could be repeated as long as needed.

End of alert signal with 30 seconds of un-modulated sound.

A prerecorded spoken announcement is delivered to the public using the same sirens.

Message depends on which emergency level is activated: non-failure, potential failure or imminent failure.

Emergency Alarm Siren Network

The emergency alarm siren network is composed of sufficient amount of sirens distanced not more than 2 km range and with control centres strategically located along the Wangchu Basin.

Communication between sirens and the control centre shall be performed using radio communication.

All sirens can be started remotely from the control centre of any dam. Control centre is automatically alerted in case of malfunctioning of any siren.

Maintenance of the network shall be performed once a year for cleaning the siren and surroundings.

For Bunakha HPP, the EWS shall function as a cascade-wide unified system, ensuring that an emergency declaration at Bunakha HPP automatically initiates pre-defined responses at all downstream plants (Chhukha HPP, Tala HPP, Wangchhu HPP) and the relevant Dzongkhag Disaster Management Committee (DDMC).

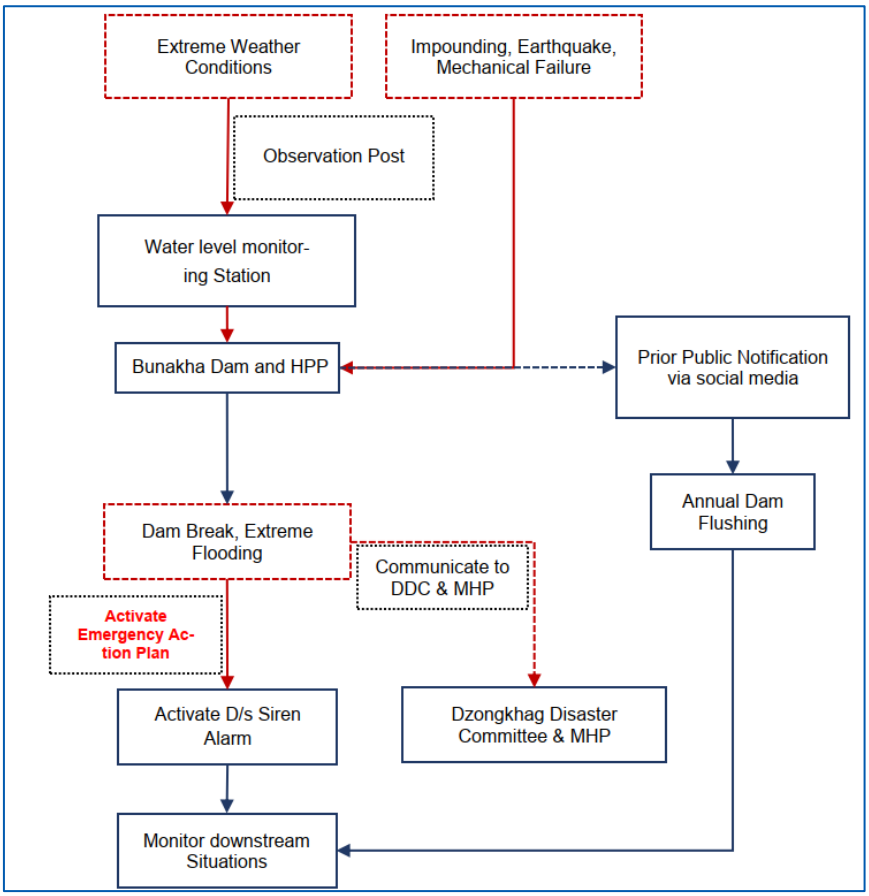
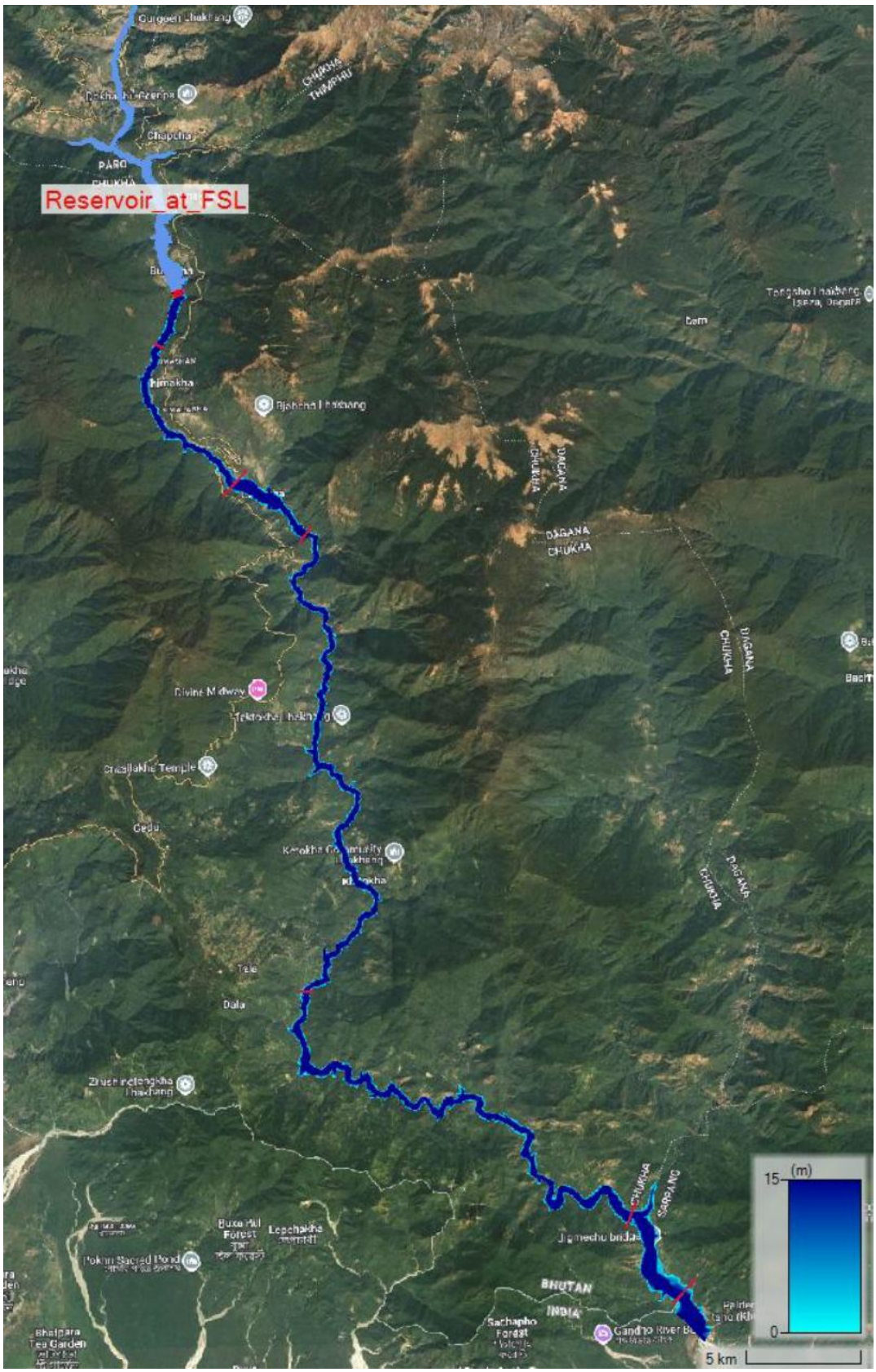


Figure 78: Early Warning System's Communication

13.5.3.8 Dam break analysis

Based on the dam safety assessment undertaken for the BHPP, the proposed dam qualifies as a large dam under ICOLD criteria, with a height of 205 m and a reservoir storage volume of approximately 224 Mm³. A dam-break analysis was undertaken using a two-dimensional HEC-RAS hydraulic model to assess downstream flood consequences under the selected project configuration. The analysis indicates that a hypothetical dam failure at Full Supply Level (FSL) could generate a peak outflow of approximately 216,000 m³/s within 12 minutes of breach initiation, resulting in rapid downstream inundation affecting settlements, hydropower infrastructure, and riverine environments. Flooding could reach major downstream receptors within 5 - 25 minutes and extend to the international border within approximately 2.5 hours. Maximum flood depths exceeding 100 m and velocities up to 20 m/s were predicted in the immediate downstream reach, demonstrating the high consequence classification of the structure. These findings are critical when considering dam safety and emergency preparedness planning.



Basemap source: Google Hybrid

Figure 79: Flood inundation mapping- showing the maximum flood depth and extent as the dam break outflow flood propagates downstream

Table 79: Observations from results of the dam break modelling at different locations downstream Location downstream of Bunakha Dam

Location downstream of Bunakha Dam	Arrival time of flood wave since dam break starts [hr.: min]			Flood Peak (m^3/s)	Max Depth (m)	Max Velocity (m/s)
	Flood Initiation	Flood Peak Time	Flood Cessatio			
Just downstream of Dam [0 km]	0:00	0:12	1:30	215965	114	16.5
At Chhukha Dam [3 km]	0:05	0:16	1:40	187360	73.5	20
At Chhukha Village [11.5 km]	0:18	0:23	2:30	173331	50	19
At Tala Dam [16.3 km]	0:25	0:32	3:30	119727	46	16
At Tala Hydropower Plant [45 km]	1:04	1:15	5:30	79286	65	11
At Jigmechu Camp Site [74 km]	2:05	2:20	10:00	48573	32	6.5
At Bhutan_India Border [80 km]	2:26	2:47	10:30	39128	24	4.5

Evacuation zones shall be located at elevations higher than the maximum flood depth indicated in the table above.**Note: Only summary of Dam Safety Emergency Preparedness Plan is shown in this plan. Details of this plan can be accessed through D6 Dam Safety Emergency Preparedness Plan of DPR.*

13.5.3.9 Affected Population and Infrastructure

Analysis of the available dam-break modelling has allowed for a high level determination of affected communities and infrastructure; as shown in the table below. Once detail design has been finalised it is recommended that a detail survey be undertaken as part of the EPP. This survey should then be repeated every 5 years to ensure validity of population and infrastructure for fast and reliable emergency response.

Table 80: Potentially affected communities and Infrastructure in the case of a dam break.

SN	Receptor Category	Potentially Affected structures
1	Major Communities	Chhukha Allay, the Jigmechu area village (near the Wangchhu River) Devitar/ Rajrukh / Tshamzhi Gosa Village
2	Existing Hydropower Infrastructure	Chhukha Hydropower Dam Chhukha Hydropower Plant Chhukha Electricity Distribution Center Tala Dam Tala Hydropower Plant
3	Thimphu - Phuentsholing Highway	Approx. 0.85 km
4	Damchu - Chhukha Bypass	Approx.0.40 km
5	Other Minor Roads	Approx.35 km

6	Suspension Bridges	Bridge 1: 26.951064°, 89.596337° Bridge 2: 26.867329°, 89.599082° Bridge 3: 26.766969°, 89.731148° Bridge 4: 26.907784°, 89.609065°
7	Road Bridges	1. Chanachen Farm raod bridge- 27.126872°, 89.539366° 2. Ta chhog Zam (Chhukha Bridge)- 27.066556°, 89.554117° 3. Wangchhu Bridge - 27.051035°, 89.574182° 4. Bridge- 26.966337°, 89.599311° 5. Jigmechhu Bridge- 26.754924°, 89.738897° 6. Bridge - 26.855248°, 89.589532°- just below tala hydropower plant
8	Healthcare Facility	Chhukha Basic Health Unit (BHU) Hospital – 27.058234°, 89.563553°
9	Educational Institutions	Wangchhu MSS School- 27.056172°, 89.564159° Tshamzhi Gosa(Devitar) school- 26.746920°, 89.741741°
10	Recreational Infrastructure	CHP Archery Ground – 27.056758°, 89.569393°
11	Religious Structures	chorten- 26.854681°, 89.589664° Chhorten (Stupa)- 27.056590°, 89.571158°

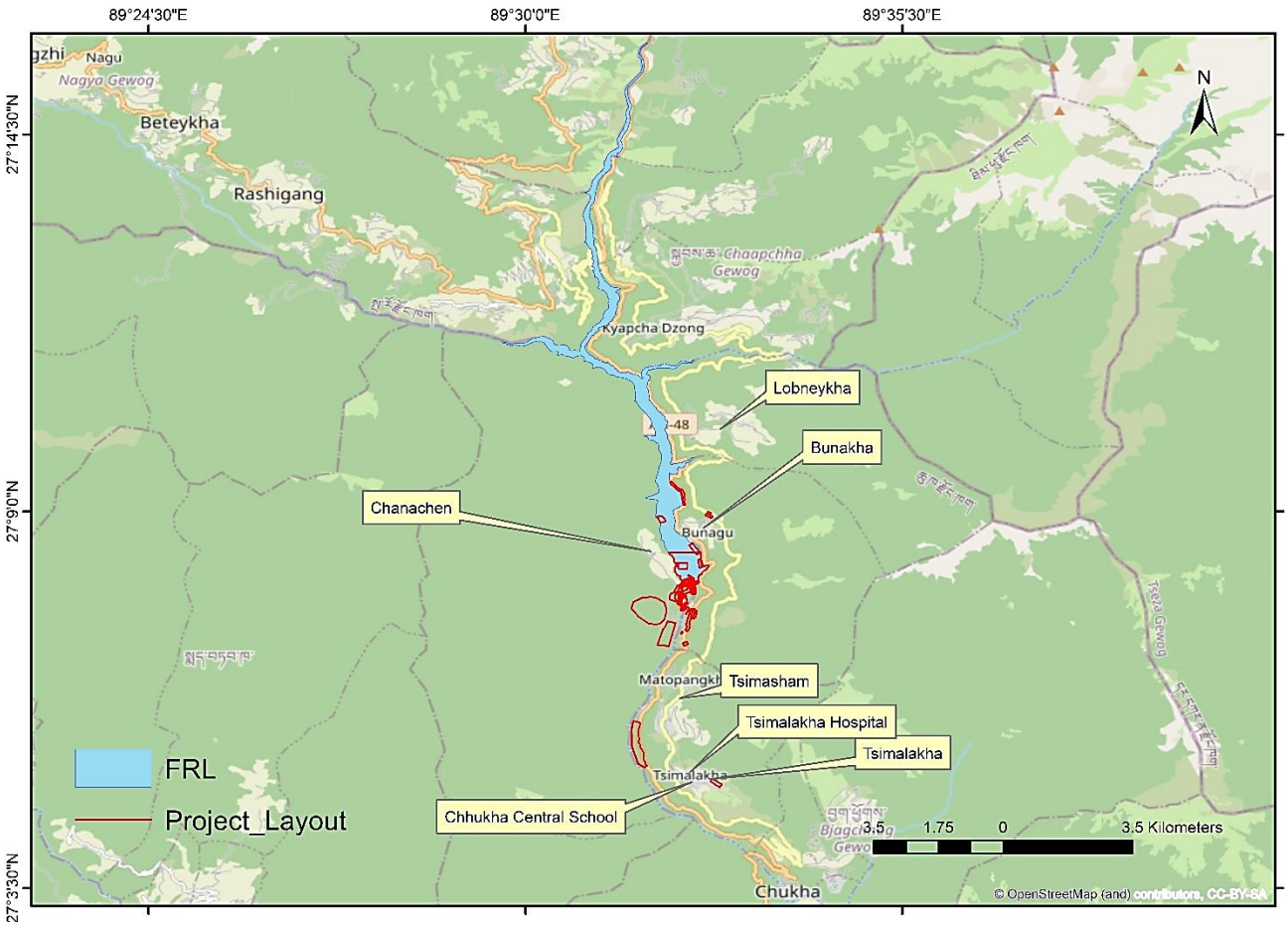


Figure 80: Map of potentially affected communities in the case of a dam break.

13.5.4 Biodiversity conservation & wildlife management plan

This Biodiversity Conservation and Wildlife Management Plan (BCWMP) has been prepared in line with the structure, terminology, and implementation approach of the approved Species Rescue Plan. The BCWMP serves as an umbrella biodiversity plan and integrates terrestrial and aquatic biodiversity management measures through coordinated implementation of the Compensatory Afforestation Plan, Species Rescue Plan, and Fisheries Conservation and Management Plan.

The BCWMP, structured in line with the Species Rescue Plan, provides a coherent and auditable framework for managing terrestrial and aquatic biodiversity impacts of the BHPP. Coordinated implementation of linked sub-plans will support the achievement of no net loss of biodiversity and Bhutan's long-term conservation objectives.

13.5.4.1 Terrestrial Biodiversity – Flora

Rescue and Conservation of Flora

Targeted flora rescue and conservation measures shall be implemented during the pre-construction phase to conserve plant species likely to be affected by vegetation clearance, infrastructure development, or reservoir submergence. Priority shall be given to medicinal plants, orchids, epiphytes, ferns, shrubs, fungi, and other conservation-significant species, in accordance with the Species Rescue Plan.

Ex-situ Conservation and Botanical Garden Support

Rescued plant species shall be conserved through approved botanical gardens or nursery facilities identified by the Department of Forests and Park Services (DoFPS). Ex-situ conservation, propagation, and research activities shall be coordinated with national conservation institutions such as National Biodiversity Centre.

Minimization of Vegetation Clearance

Vegetation clearance shall be strictly limited to the approved project footprint. Only trees and vegetation officially marked by DoFPS shall be removed. Unauthorized clearing outside designated areas shall be prohibited.

Rehabilitation and Restoration of Disturbed Areas

All temporarily disturbed areas shall be rehabilitated following construction using native and site-appropriate species. Restoration measures shall be implemented in coordination with the Compensatory Afforestation Plan to enhance ecological recovery and habitat connectivity.

13.5.4.2 Terrestrial Biodiversity – Fauna

Wildlife Rescue and Release

A wildlife rescue, treatment, and release program shall be implemented in coordination with DoFPS. If wildlife is injured or distressed due to project activities, immediate notification and

response shall be undertaken following approved protocols. All wildlife encounters shall be recorded.

Wildlife Survey and Monitoring

Wildlife surveys and monitoring, including camera trapping, shall be conducted through the DoFPS to understand species presence, movement patterns, and habitat use. Monitoring results shall inform adaptive management.

Anti-Poaching Measures

To mitigate increased poaching risks due to improved access, awareness programs for workers and contractors shall be conducted. Support to DoFPS for patrolling and community-based vigilance mechanisms shall be provided where necessary.

Human–Wildlife Conflict Mitigation

Community-based human–wildlife conflict mitigation measures shall be supported in coordination with local authorities and DoFPS, including pilot interventions and adaptive scaling based on effectiveness.

13.5.4.3 Aquatic Biodiversity

Fisheries Conservation and Management

Aquatic biodiversity and fisheries resources shall be managed in accordance with the Fisheries Conservation and Management Plan (FCMP). Key measures include environmental flow management, fish rescue and relocation, protection of conservation-significant fish species, invasive species control, and aquatic habitat restoration.

C.2 Environmental Flow and Habitat Protection

Environmental flows shall be maintained to sustain downstream aquatic habitats and fish life-cycle requirements. In-river works shall be minimized during critical breeding periods, and sediment and pollution controls shall be strictly enforced.

13.5.4.4 Institutional Responsibilities

Implementation of the BCWMP shall be the responsibility of the BHPLand its contractors. DoFPS shall provide technical oversight, while the Biodiversity Management Committee (BMC) under PMU shall coordinate implementation, monitoring, and adaptive management. The Supervision Consultant shall ensure compliance and reporting.

13.5.4.5 Monitoring, Reporting, and Adaptive Management

Monitoring and reporting requirements for biodiversity management shall follow the schedules and indicators defined in the Compensatory Afforestation Plan, Species Rescue Plan, and FCMP. Results shall be consolidated in Environmental and Social Monitoring Reports, and adaptive measures shall be implemented where required.

Note: *No separate implementation and Monitoring Schedule and cost are incorporated under this BCWMP. All biodiversity-related activities and costs are integrated within the Compensatory*

Afforestation Plan, Species Rescue Plan, and Fisheries Conservation and Management Plan budgets to avoid duplication and ensure transparency.

13.5.5 Species rescue plan

The Species Rescue Plan for the BHPP has been developed to avoid, minimize, and mitigate potential impacts of project activities on flora and fauna within the project influence area, in line with Bhutan's conservation policies and international good practice. Given the ecological sensitivity of the Bunakha landscape and the presence of diverse and conservation-significant plant and wildlife species, the plan adopts a precautionary and proactive approach focusing on pre-construction rescue, ex-situ conservation, habitat restoration, wildlife rescue and release, anti-poaching measures, and mitigation of human–wildlife conflict. The plan emphasizes close coordination with national and local conservation institutions to ensure that biodiversity values are safeguarded throughout the construction and operation phases of the project.

13.5.5.1 Flora

Rescue of Flora

The Bunakha HPP will implement a targeted flora rescue program during the pre-construction phase to conserve plant species likely to be affected by vegetation clearance, infrastructure development, or reservoir submergence. Priority will be given to medicinal plants, orchids, epiphytes, ferns, shrubs, fungi, and other conservation-significant species.

Pre-construction surveys will be undertaken in areas proposed for dam works, submergence area, access roads, construction camps, and muck disposal sites in coordination with the Department of Forests and Park Services (DoFPS) and the National Biodiversity Centre (NBC). Species identified for conservation will be rescued and transferred to approved ex-situ conservation facilities. The scope of surveys, species selection, and rescue protocols will be finalized through agreed Terms of Reference with the relevant authorities.

Conservation of rescued plant species in Botanical Garden

Rescued plant species will be conserved in the existing or designated Botanical Garden facilities, with the Royal Botanical Garden at Serbithang, Thimphu as primary and official botanical garden in Bhutan managed by the National Biodiversity Centre. The garden is a living repository for native plant genetic diversity, rescue center for threatened species and venue for promoting environmental education. Ex-situ conservation of threatened plant species from Bunakha project area will be undertaken in collaboration with NBC.

Ensure Minimal Land Clearing and Removal of Vegetation

Vegetation clearance will be strictly limited to the approved project footprint. Only trees and vegetation officially marked by DoFPS will be felled and forest clearing in the submergence areas, and unauthorized clearing outside designated areas will be prohibited.

Rehabilitate and Restore all Cleared Sites

All temporarily disturbed areas will be restored following construction using native and fast-growing species, in coordination with the Compensatory Afforestation Plan. Where appropriate,

selected species conserved through ex-situ measures may be replanted to enhance ecological recovery.

13.5.5.2 Fauna

Wildlife Rescue and Release

A wildlife rescue, treatment, and release program will be implemented in coordination with the Department of Forests and Park Services (DoFPS), in accordance with the approved EMP. In the event that wildlife is found injured or distressed due to project activities, the contractor shall immediately coordinate with DoFPS and the concerned Gedu Forest Office to undertake appropriate rescue measures. Affected wildlife will be safely captured, treated, rehabilitated, and released into suitable habitats following established protocols. All wildlife encounters during the pre-construction and construction phases will be systematically recorded. Detailed procedures, roles, and institutional arrangements for wildlife rescue and management will be reviewed and endorsed by the Biodiversity Management Committee.

Wildlife Survey and Monitoring

Wildlife surveys and monitoring, including camera trapping, will be conducted in the project area and surrounding biological corridors to strengthen the understanding of wildlife presence and movement patterns in coordination with DoFPS. Monitoring will support long-term conservation planning, with particular attention to key and protected species. Survey objectives and methodologies will be agreed with the Biodiversity Management Committee.

During construction, contractors will immediately notify the Gedu Forest Office in the event of wildlife encounters or accidental injuries, and rescue actions will follow DoFPS-approved protocols.

Anti-Poaching Measures

To address increased accessibility and potential poaching risks associated with project infrastructure, the following measures will be implemented:

i. Awareness

With the construction of the access road to the dam and a bridge across the river from the dam site, the accessibility of humans to forest areas will increase, which may increase the risk of poaching. The wildlife is also at risk from poaching by construction workers, so awareness raising will be an important means to mitigate this risk. Mandatory awareness programs for workers and contractors on wildlife protection laws, penalties, and zero tolerance for poaching shall be conducted.

ii. Patrolling

To minimize the risks of poaching, in addition to awareness programs, support to DoFPS through the provision of basic patrolling equipment and facilitation of community-based vigilance mechanisms to alert forestry officials of any illegal activities in the worker camps or at project sites.

iii. Build up Scientific Database

The project will provide assistance to DoFPS in strengthening biodiversity databases and supporting wildlife research and monitoring initiatives.

Mitigation of Human-Wildlife Conflict

To reduce crop damage and livestock losses, the project will support the preparation and implementation of community-based human–wildlife conflict mitigation measures, in coordination with local authorities and DoFPS. Pilot interventions will be tested at selected sites and scaled up based on effectiveness.

Institutional Responsibilities:

Implementation and oversight of the Rescue Plan will be coordinated by the Biodiversity Management Committee, in collaboration with relevant government agencies, conservation institutions, forest authorities, and local administrations, under the overall responsibility of the BHPL.

Table 81: Estimated Cost

Cost Item	Description	Unit	Estimated Quantity	Unit Cost (BTN)	Estimated Total Cost (BTN)
Pre-construction biodiversity survey	Flora and fauna survey for rescue planning (specialist support)	Lump sum	1	2,000,000	2,000,000
Preparation of rescue protocols	Development of flora and fauna rescue and handling procedures	Lump sum	1	800,000	800,000
Flora rescue operations	Rescue, handling, and transport of priority plant species	Lump sum	1	1,600,000	1,600,000
Ex-situ conservation support	Support to botanical garden/nursery for propagation and care	Lump sum	1	1,200,000	1,200,000
Wildlife rescue and treatment	Emergency rescue, veterinary care, medicines, and release	Provisional sum	1	2,400,000	2,400,000
Wildlife awareness training	Training and awareness programs for workers and staff	Lump sum	1	600,000	600,000
Monitoring and reporting	Wildlife encounter logging, survival monitoring, and reporting	Lump sum	1	1,000,000	1,000,000
Contingency (10%)	Unforeseen rescue and mitigation requirements	Lump sum	1	480,000	960,000
TOTAL					**10,560,000**

Table 82: Species Rescue Plan Implementation and Monitoring Schedule

Activities	Project Phase	Implementation Responsibility	Monitoring / Oversight Responsibility	Monitoring Indicators	Frequency / Timing	Reporting
Pre-construction survey for identification of flora and fauna requiring rescue	Pre-construction	Contractor with DoFPS / NBC	Supervision Consultant / Biodiversity Management Committee (BMC)	Survey report approved; priority species list prepared	Once, before site clearance	Quarterly E&S Report
Preparation of species rescue and handling protocols	Pre-construction	Contractor in coordination with DoFPS and Park Office	BMC	Approved rescue protocol available at the site	Once, before construction	Quarterly E&S Report
Rescue of flora from areas affected by clearance or submergence	Pre-construction	Contractor with DoFPS / NBC	Supervision Consultant	Number and type of species rescued	As required before clearance	Monthly E&S Report
Transfer of rescued flora to botanical garden / ex-situ facility	Pre-construction	DoFPS / NBC	Supervision Consultant	Transfer records; survival rate	Continuous during rescue	Quarterly E&S Report
Wildlife awareness and induction training for workers	Pre-construction & Construction	Contractor	Supervision Consultant	Training records; attendance sheets	Before mobilization and quarterly refreshers	Monthly E&S Report
Wildlife rescue, treatment, and release (if encountered)	Construction	Contractor (notification) with DoFPS & Park Office	Supervision Consultant / BMC	Rescue and release records	As required	Incident Report / Monthly E&S Report
Recording and reporting of wildlife encounters	Pre-construction & Construction	Contractor	Supervision Consultant	Wildlife encounter log maintained	Continuous	Monthly E&S Report

Activities	Project Phase	Implementation Responsibility	Monitoring / Oversight Responsibility	Monitoring Indicators	Frequency / Timing	Reporting
Monitoring the survival of rescued flora	Construction & Early Operation	DoFPS / Botanical Garden Authority	BMC	Survival percentage; plant health	Bi-annually	Bi-annual Monitoring Report
Restoration of temporary work sites using native species	Construction & post-construction	Contractor	Supervision Consultant	Area restored; species used	After completion of the works	Completion Report
Performance review and corrective actions	Construction & post-construction	Supervision Consultant	BMC	Compliance status: corrective actions implemented	Quarterly	Quarterly E&S Report

13.5.6 Greenbelt development plan

The Greenbelt Development Plan for the BHPP has been prepared to comply with the requirements of IFC Performance Standard 6 (Biodiversity Conservation and Sustainable Management of Living Natural Resources), the ADB Safeguard Policy Statement (2009), and relevant Bhutanese national regulations and technical guidelines issued by the Department of Forests and Park Services (DoFPS).

The plan aims to mitigate adverse impacts on terrestrial habitats arising from project construction and operation, restore temporarily disturbed areas, enhance ecosystem services, and contribute to long-term ecological stability of the project area. In line with the mitigation hierarchy (avoid–minimize–restore–offset) prescribed under IFC PS6 and ADB SPS, greenbelt development is designed as a restoration and enhancement measure for disturbed forest land, slopes, road corridors, reservoir margins, and project facilities.

Objectives and Safeguard Alignment

The key objectives of greenbelt development at Bunakha HPP are to:

- Restore and stabilize project-affected land and slopes, consistent with ADB SPS requirements on rehabilitation of temporary impacts;
- Maintain ecological integrity and connectivity of surrounding forest habitats using native species, as required under IFC PS6 (paras 7–13);
- Reduce secondary impacts such as soil erosion, sedimentation, dust, and noise during construction, supporting pollution prevention and resource efficiency objectives; and
- Implement afforestation and revegetation measures in accordance with Bhutan DoFPS afforestation, slope stabilization, and watershed management guidelines.

13.5.6.1 Survey and Identification of Greenbelt Areas

In compliance with IFC PS6 baseline and impact assessment requirements and ADB SPS Annex 1, a joint survey will be conducted by the Project Management Unit and forestry/environment staff to identify suitable areas for greenbelt development. The survey will specifically assess:

- Areas susceptible to erosion, landslides, or slope instability, particularly around the reservoir rim, adits, muck disposal sites, and access roads;
- Temporarily disturbed areas requiring rehabilitation following construction;
- Available spaces around the dam complex, powerhouse, camps, and ancillary facilities for establishment of vegetative buffers; and
- Existing habitat characteristics, soil conditions, slope gradients, drainage patterns, and dominant vegetation types to ensure habitat-appropriate species selection, as required under IFC PS6 (use of native species and avoidance of invasive species).

13.5.6.2 Prioritization and Phased Implementation

Greenbelt development will be prioritized in areas where construction activities are completed or substantially progressed, consistent with ADB SPS requirements for the timely restoration of temporarily affected land. A phased implementation schedule will be prepared, incorporating:

- Construction sequencing and site readiness;
- Seasonal suitability for plantation and revegetation activities;

- Water availability and maintenance requirements; and
- Species-specific planting methods and survival considerations.

High-risk erosion zones, muck disposal areas, and road cut slopes will be addressed as first-priority sites to reduce cumulative environmental impacts.

13.5.6.3 Integration with Slope Stabilization and Engineering Measures

In accordance with DoFPS watershed and slope management guidelines and ADB SPS environmental management requirements, greenbelt development will be integrated with structural stabilization measures. Engineering interventions such as retaining walls, gabion/crate walls, toe protection, check drains, and stream bank treatments will be implemented before or concurrently with plantation works. Vegetative measures will complement structural works to enhance long-term slope stability, reduce sediment yield, and promote natural regeneration.

13.5.6.4 Plantation Strategy and Species Selection

Greenbelt development will include avenue plantations along access roads and approach roads to adits, vegetative buffers around the reservoir rim and project facilities, and rehabilitation of muck disposal sites. All plantation activities will use native and locally adapted tree, shrub, and ground cover species, consistent with IFC PS6 requirements on biodiversity conservation and sustainable management of living natural resources.

Plantation areas will be protected using appropriate fencing or bio-engineering measures to prevent grazing and anthropogenic disturbance. This approach aligns with DoFPS afforestation and forest restoration practices and supports ADB SPS objectives on ecosystem restoration and enhancement.

Greenbelt development will be closely coordinated with the Compensatory Afforestation Plan, ensuring that disturbed project land is rehabilitated in a planned and systematic manner, thereby minimizing pressure on external forest areas.

13.5.6.5 Monitoring, Maintenance, and Budgetary Provisions

In line with IFC PS6 monitoring and adaptive management requirements, and ADB SPS environmental monitoring obligations, regular monitoring will be undertaken to assess plantation survival rates, growth performance, and overall effectiveness of greenbelt measures. Monitoring results will inform adaptive management actions, including gap planting, or enhanced protection where required. Maintenance activities such as watering, weeding, replacement planting, and protection will be carried out during the establishment period to ensure long-term sustainability.

Financial provisions for implementation, monitoring, and maintenance of greenbelt development will be included under the Biodiversity Conservation and Wildlife Management Plan, and Compensatory Afforestation Plan, consistent with ADB SPS requirements for costed and implementable environmental management measures and DoFPS financial and implementation norms

13.5.7 Fisheries conservation and management plan

This Fisheries Conservation and Management Plan (FCMP) has been prepared to avoid, minimize, and mitigate potential impacts of the BHPP on fish populations and aquatic habitats of

the Wangchhu River. The plan applies to the pre-construction, construction, and operation phases and covers upstream reaches, the reservoir area, environmental flow (E-flow) reaches, downstream sections, and affected tributaries. The FCMP is an integral part of the ESIA and is aligned with the Biodiversity Management Plan, Species Rescue Plan, Environmental Flow Assessment, and ESMP.

Multi-season aquatic biodiversity surveys indicate that the Wangchhu River supports native and conservation-significant fish species, with higher diversity in downstream reaches and lower diversity in high-gradient upstream sections. Species of conservation concern recorded include *Tor putitora* (Endangered), *Schizothorax richardsonii* (Vulnerable), and *Semiplotus semiplotus* (Vulnerable). Fish distribution and abundance are closely linked to seasonal flow variability, substrate composition, and water quality. Implementation of this FCMP ensures compliance with Bhutanese environmental regulations, ADB Safeguard Policy Statement (2009), and IFC Performance Standard 6, supporting sustainable hydropower development while safeguarding fisheries resources

13.5.7.1 Key Risks to Fisheries

Potential project-related risks include interruption of longitudinal fish movement, alteration of natural flow regimes, loss or modification of lotic habitats due to reservoir impoundment, temporary fish mortality or stranding during construction, increased sedimentation, and risk of invasive or non-native species proliferation. Cumulative effects from existing upstream and downstream hydropower schemes are also recognized.

13.5.7.2 Mitigation and Management Measures

The following measures shall be implemented:

Environmental Flow Management: Maintain ecologically appropriate environmental flows downstream of the dam, reflecting seasonal variability and supporting fish movement, spawning cues, and prey availability.

Fish Rescue and Relocation: Where construction activities (e.g., cofferdams, diversion works, dewatering) pose an imminent risk to fish, controlled rescue and relocation shall be undertaken in coordination with the Department of Forests and Park Services (DoFPS), using approved handling and release protocols.

Protection of Conservation-Significant Species: Construction activities in habitats identified for threatened and vulnerable species shall be minimized, and additional protection measures applied during sensitive life-cycle periods.

Invasive Species Management: Intentional stocking of non-native fish species shall be prohibited. Awareness programs shall discourage prayer animal release and illegal introductions. Existing non-native species populations shall be monitored.

Habitat Protection and Restoration: Temporarily disturbed riverbanks and aquatic habitats shall be rehabilitated using bio-engineering techniques and native riparian vegetation, restoring natural channel morphology where feasible.

Construction Controls: In-river works shall be minimized during peak breeding seasons, and strict sediment, pollution, and wastewater controls shall be enforced.

13.5.7.3 Monitoring and Adaptive Management

A fishery monitoring program shall be implemented throughout construction and operation, covering fish diversity and abundance, critical habitats, water quality, invasive species presence, and environmental flow compliance. Monitoring results shall be reported through routine Environmental and Social Monitoring Reports. The FCMP shall be reviewed annually and updated based on monitoring outcomes and regulatory guidance.

13.5.7.4 Institutional Responsibilities

BHPL is responsible for FCMP implementation through contractors. DoFPS shall provide technical oversight, and the Biodiversity Management Committee shall coordinate fisheries-related actions. The Supervision Consultant shall monitor compliance and reporting.

Table 83: Estimated Cost

Cost Item	Description	Unit	Estimated Quantity	Unit Cost (BTN)	Estimated Total Cost (BTN)
Pre-construction fisheries survey	Targeted fisheries survey for rescue planning and habitat verification (specialist support)	Lump sum	1	1,500,000	1,500,000
Preparation of fisheries rescue & handling protocols	Development of fish rescue, relocation, and handling procedures (DoFPS-approved)	Lump sum	1	600,000	600,000
Fish rescue and relocation operations	Capture, handling, transport, and release during dewatering or cofferdam works	Provisional sum	1	2,000,000	2,000,000
Environmental flow compliance monitoring	Flow measurement, compliance checks, and reporting during construction and early operation	Lump sum	1	1,200,000	1,200,000
Fisheries biodiversity monitoring	Seasonal fish surveys, CPUE analysis, and habitat assessment (2–3 years)	Lump sum	1	2,200,000	2,200,000
Invasive species monitoring and management	Monitoring of non-native species and implementation of awareness measures	Lump sum	1	800,000	800,000

Cost Item	Description	Unit	Estimated Quantity	Unit Cost (BTN)	Estimated Total Cost (BTN)
Worker and community awareness programs	Training and awareness on fisheries protection and the prohibition of illegal fishing	Lump sum	1	500,000	500,000
Aquatic habitat restoration support	Bio-engineering, riverbank stabilization, and minor habitat enhancement works	Provisional sum	1	1,500,000	1,500,000
Monitoring, documentation, and reporting	Maintenance of fisheries logs, monitoring records, and ESMP reporting	Lump sum	1	900,000	900,000
Contingency (10%)	Unforeseen fisheries rescue or mitigation requirements	Lump sum	1	-	1,120,000
Total Estimated FCMP Cost					12,320,000

Table 84: Fisheries Conservation and Management Plan Implementation and Monitoring Schedule

Activity	Project Phase	Implementation Responsibility	Monitoring / Oversight Responsibility	Monitoring Indicators	Frequency / Timing	Reporting
Pre-construction fisheries survey and verification of critical habitats	Pre-construction	Contractor with Fisheries Specialist, DoFPS	Supervision Consultant / Biodiversity Management Committee (BMC)	Survey report approved; list of priority species and habitats finalized	Once, before site clearance	Quarterly Environmental & Social (E&S) Report
Preparation of fish rescue and handling protocols	Pre-construction	Contractor in coordination with DoFPS	BMC / Supervision Consultant	Approved rescue and handling protocol available at the site	Once, before the commencement of construction	Quarterly E&S Report
Fish rescue and relocation during dewatering or cofferdam works	Construction	Contractor (implementation) with DoFPS support	Supervision Consultant / BMC	Number of fish rescued and relocated; survival condition at release	As required during dewatering activities	Incident Report / Monthly E&S Report
Implementation of environmental flow releases	Construction & Operation	BHPL	Supervision Consultant / DoFPS	Flow release records; compliance with approved E-flow regime	Continuous	Monthly & Quarterly E&S Reports
Fisheries biodiversity monitoring (fish diversity and abundance)	Construction & Operation	Fisheries Specialist / Contractor	Supervision Consultant / BMC	Species richness, CPUE; presence of conservation-significant species	Biannually (pre- and post-monsoon)	Bi-annual Fisheries Monitoring Report
Monitoring of invasive and non-native fish species	Construction & Operation	Fisheries Specialist / Contractor	Supervision Consultant / DoFPS	Presence/abundance of non-native species; trend analysis	Annually	Annual Biodiversity Monitoring Report

Activity	Project Phase	Implementation Responsibility	Monitoring / Oversight Responsibility	Monitoring Indicators	Frequency / Timing	Reporting
Worker and community awareness on fisheries protection	Pre-construction & Construction	Contractor	Supervision Consultant	Training records, attendance sheets, and awareness materials were displayed	Before mobilization and refresher, every 6 months	Monthly E&S Report
Aquatic habitat restoration and riverbank stabilization	Construction & Post-construction	Contractor	Supervision Consultant / BMC	Area restored; habitat stability; vegetation survival	After completion of the works in each section	Completion Report
Recording and reporting of fish mortality or unusual observations	Construction & Operation	Contractor / Operator	Supervision Consultant	Incident log maintained; corrective actions implemented	Continuous	Incident Report / Monthly E&S Report
Performance review and adaptive management	Construction & Operation	Supervision Consultant	Biodiversity Management Committee	Compliance status: corrective actions identified and closed	Annually	Annual ESMP Performance Review

13.5.8 Air quality and noise management plan

The construction of the BHPP involves massive earth-moving activities (5.65 million m³ of excavation), tunneling, explosive rock blasting, and the operation of heavy industrial crushers and batching plants. Due to topographical constraints, the most intense industrial facilities-including the primary quarry (INRQ-3), crushing units, and RCC/CVC batching plants are co-located on the right bank, directly adjacent to Chanachen Village, transforming it into a critical impact hotspot.

The 2025 physical baseline survey established two vital constraints:

- The AH48 highway corridor already experiences NO_2 levels exceeding WHO guidelines, leaving zero assimilative capacity for additional emissions.
- The villages of Chanachen and Nayakha currently enjoy a pristine acoustic environment (night-time levels of 36–40 dBA), meaning any unmitigated industrial noise will cause severe acoustic shock and community distress.

This Air Pollution and Noise Management Plan establishes the mandatory engineering, operational, and monitoring controls required to protect human health, cultural heritage, and local biodiversity, ensuring strict compliance with Bhutanese Environmental Standards (ES 2020), WHO guidelines, and the ADB Safeguard Policy Statement (SPS 2009).

13.5.8.1 Environmental and Health Risks

Without rigorous, engineered emission and acoustic controls, the project will trigger the following severe impacts:

Respiratory & Cardiovascular Health: Fugitive dust from the quarries, haul roads, and crushers contains fine particulate matter (PM_{10}, $PM_{2.5}$) and crystalline silica. Inhalation causes acute respiratory distress, exacerbates asthma, and poses long-term silicosis risks to both workers and the Chanachen community.

Acoustic Intrusion & Sleep Disturbance: Unrestricted night-time operation of heavy machinery, crushers (100-110 dB), and haul trucks (80-90 dB) will shatter the pristine 36-40 dBA baseline of local villages, causing severe sleep deprivation, stress, and community hostility.

Vibration Damage to Cultural Heritage: Explosive blasting at INRQ-3 generates intense ground vibrations (Peak Particle Velocity - PPV) and overpressure. Uncontrolled blasting threatens the structural integrity of spiritually revered and historically significant sites, particularly Lamche Bja (Elephant Cliff) and Bunakha Lhakhang.

Agricultural & Ecological Degradation: Heavy dust deposition on surrounding agricultural terraces will block stomata and reduce crop yields. High-decibel noise disrupts avian and mammalian communication and breeding patterns in the adjacent forest corridors.

13.5.8.2 Mandatory Mitigation Measures (Phase-Wise)

Implementation of these measures is the strict responsibility of the EPC Contractor, subject to enforcement by the PSC and BHPL.

Pre-Construction Phase (Planning & Baselines)

Pre-Condition Structural Surveys: Before any blasting operations commence, the Contractor must conduct a mandatory, documented photographic and structural dilapidation survey of all residential and religious structures in Chanachen and Bunakha (including Bunakha Lhakhang and Lamche Bja) to establish a baseline against future vibration damage claims.

Equipment Procurement: All heavy machinery, excavators, and diesel generators procured for the project must meet national emission standards and be equipped with OEM-specified acoustic mufflers and exhaust silencers.

Construction Phase (Active Air Quality Control)

Mandatory Dust Suppression:

- The Contractor must deploy dedicated water sprinkling to continuously spray all unpaved internal haul roads, active excavation faces, and muck disposal (MD) sites.
- Crucially, water for dust suppression must be drawn exclusively from the Wangchhu River, not from community drinking water springs (e.g., SW-10).

Transport Controls: All trucks transporting sand, aggregates, or muck must be securely covered with heavy-duty tarpaulins. A strict speed limit of 20 km/h must be enforced in all village zones (Chanachen, Bunakha, Tshimalakha) to drastically reduce dust re-suspension and noise.

Vehicle Emissions (NOx Management): To mitigate compounding impacts on the already stressed AH48 corridor, the Contractor must enforce a strict 5-minute maximum idling rule for all heavy vehicles. All project machinery must undergo documented exhaust emission testing every six months.

Construction Phase (Active Noise & Vibration Control)

Acoustic Buffering & Curfews: Night-time operations (22:00 to 06:00) for rock crushing, blasting, and heavy aggregate haulage are strictly prohibited.

Controlled Blasting Protocols:

- Blasting at INRQ-3 (located just 100m from Chanachen Village) must utilize controlled techniques, including micro-delay detonators, pre-splitting, and heavy blast mats to minimize PPV and eliminate flyrock.
- A strict community warning system must be implemented as indicated in Blasting Operation Plan.

Occupational Hearing Protection: All workers operating near crushers, drills, or in the underground access tunnel must be provided with, and mandated to wear, high-grade earplugs or earmuffs.

Operation Phase (Long-Term Management by BHPL

Greenbelt Development: BHPLwill maintain thick, multi-tiered greenbelts of native, broad-leaf trees around the powerhouse, switchyard, and administrative colony. These act as natural bio-filters for dust and acoustic dampeners.

Occupational Exposure: Implement strict occupational noise exposure limits (8-hour Time-Weighted Average ≤85 dBA) inside the powerhouse. Staff entering the turbine halls must wear appropriate PPE.

Decommissioning Phase

Demolition Dust Control: The dismantling of temporary batching plants, coffer dams, and camps must be accompanied by continuous water spraying to suppress concrete and soil dust. Debris transport trucks must remain covered until the site is fully restored.

13.5.8.3 Monitoring and Compliance Program

Table 85: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
Ambient Air Quality	PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO	Continuous (CAAQMS) & Monthly Manual	ANSP-2 (Tshimalakha), ANSP-4 (Bunakha), ANSP-10 (Chanachen), ANSP-9	Contractor / PSC
Ambient Noise	Leq (Day/Night), Lmax	Continuous & Weekly Spot Checks	ANSP-4, ANSP-9, ANSP-10	Contractor / PSC
Vibration (Blasting)	Peak Particle Velocity (PPV)	During every blast event	Lamche Bja, Bunakha Lhakhang, Chanachen edge	Blasting Specialist / PSC
Dust Suppression	Visual inspection of roads/stockpiles; water sprinkling logs	Daily	All active work sites & haul roads	PSC
Vehicle Emissions	Smoke opacity, exhaust integrity	Bi-Annually	Main Workshop	Contractor / PSC
Community Grievances	Complaints regarding dust, noise, or structural cracks	Monthly	Chanachen, Bunakha, Nayakha	BHPL/ PSC

13.5.8.4 Resources Required

Noise & Vibration Engineering: Acoustic enclosure panels for generators and crushers; micro-delay detonators and heavy blast mats; continuous seismographs/accelerometers.

Monitoring Instruments: Continuous Ambient Air Quality Monitoring Stations (CAAQMS); Class-1 handheld sound level meters; portable opacity meters for vehicle exhausts.

Personnel & PPE: Certified Blasting Engineer; dedicated environmental monitors (PSC); N95 respirators, earplugs, and earmuffs for the entire workforce.

13.5.8.5 Institutional Arrangements

EPC Contractor: Legally and financially responsible for procuring all emission controls, installing acoustic barriers, enforcing speed limits, and executing controlled blasting. Must submit a detailed Blasting Operation Plan to the PSC prior to rock excavation.

PSC (Supervision Consultants): Reviews and approves the C-ESMP and Blasting Plan. Deploys field engineers to monitor PPV during blasts. Holds the authority to immediately suspend blasting or crushing operations if PPV thresholds are exceeded or night-time curfews are violated.

BHPL (Environmental Social, Health and Safety Unit): Oversees overall project compliance, manages the Grievance Redress Mechanism (GRM) for community noise/dust complaints, and leads the pre-construction dilapidation surveys.

Regulatory Agencies (NEC, DoFPS, DoW): Conduct periodic compliance monitoring to ensure adherence to Bhutan Environmental Standards (ES 2020) and review all CAAQMS data.

13.5.9 Labor management plan

The Labor Management Plan (LMP) for the Project has been prepared to manage labor arrangements and labor risks during the implementation of the Project. This LMP shall be in line with national requirements as well as the requirements of the ADB SPS 2009. The Project is responsible for implementing the plan in compliance with the proposed risk mitigation actions and with national and ILO standards.

The LMP document has been prepared to ensure proper working conditions and management of worker relationships, occupational health and safety, and to address Project-related issues associated with workforce-related gender-based violence, (GBV); and/or sexual exploitation and abuse and sexual harassment (SEAH). The LMP document is a “live document” that can be updated to meet the demands of the Project.

13.5.9.1 Purpose

The purpose of the Labor Management Plan (LMP) is to protect project workers (including migrant workers, contracted workers and community workers) and their rights, and to ensure that the Project complies with the requirements of the ADB’s Safeguard Policy Statement and the Labor and Employment Act of Bhutan.

13.5.9.2 Key Principle and definitions

The following key principles are followed by the project ensure the compliance as required by ADB SPS and national legislation.

- Promote fair employment practices, including non-discrimination, equal opportunities, and respect for workers' rights.
- To prevent the use of all forms of forced labor and child labor.
- To protect project workers, including vulnerable workers such as women, persons with disabilities, children (of working age, in accordance with ADB SPS and national legislation) and migrant workers, contracted workers, community workers and primary supply workers, as appropriate.

- To mitigate the risks of sexual exploitation and abuse and sexual harassment (SEAH) in the workplace and the project affected community
- Safeguard the health and safety of all workers and prevent accidents or occupational hazards.
- To support the principles of freedom of association and collective bargaining of project workers in a manner consistent with national law and meet ADB standards.
- Encourage capacity building and skill development among the local workforces.
- Foster effective communication channels between workers, management, and relevant stakeholders.
- Ensure employees are aware of their rights and entitlements including pay, leave, sick and bereavement leave, and rest breaks.
- Deliver a fair and equitable environment that includes mechanisms for responding to, and resolving, employees' questions and concerns, while ensuring employee relations issues are managed justly, and in a coordinated and consistent manner, while providing project workers with accessible means to raise workplace concerns.
- Provides guidance to workers on expected behaviors through a Code of Conduct

13.5.9.3 Legal requirements

13.5.9.3.1 Social Protection Requirements

ADB's Social Protection Strategy (2001 SPS) requires the Borrower to comply with applicable labor laws in relation to the Project, and take the following measures to comply with the core labor[1] standards6 for the ADB financed portion of the Project:

a) carry out its activities consistent with the intent of ensuring legally permissible equal opportunity, fair treatment and non-discrimination in relation to recruitment and hiring, compensation, working conditions and terms of employment for its workers (including prohibiting any form of discrimination against women during hiring and providing equal work for equal pay for men and women engaged by the Borrower);
b) not restrict its workers from developing a legally permissible means of expressing their grievances and protecting their rights regarding working conditions and terms of employment;
c) engage contractors and other providers of goods and services:
   i. who do not employ child Labour[2] or forced labour[3]
   ii. who have appropriate management systems that will allow them to operate in a manner which is consistent with the intent of (A) ensuring legally permissible equal opportunity and fair treatment and non-discrimination for their workers, and (B) not restricting their workers from developing a legally permissible means of expressing

[1] the core labor standards are the elimination of all forms of forced or compulsory labor; the abolition of child labor; elimination of discrimination in respect of employment and occupation; and freedom of association and the effective recognition of the right to collective bargaining, as per the relevant conventions of the International Labor Organization;

[2] child labour means the employment of children whose age is below the statutory minimum age of employment in the relevant country, or employment of children in contravention of International Labor Organization Convention No. 138 'Minimum Age Convention" (www.ioo.org)

[3] forced labour means all work or services not voluntarily performed, that is, extracted from individuals under threat of force or penalty

their grievances and protecting their rights regarding working conditions and terms of employment; and

iii. whose subcontracts contain provisions which are consistent with paragraphs (i) and (ii) above

13.5.9.3.2 National legislations

Below key legal instruments will be attracted and complied in implementing LMP

- The Constitution of the Kingdom of Bhutan
- Labor and Employment Act of Bhutan 2007
- Regulation on Working Conditions, 2022
- Regulation on Occupational Health and Safety for Construction Industry, 2022
- Regulation on Occupational Health, Safety and Welfare, 2022
- Regulation on Foreign Workers Management, 2022

13.5.9.4 Number of the Project Workers

During the pre-construction stage, approximately 39 personnel from the BHPL will be engaged to undertake planning, design review, procurement, and other preparatory activities. Throughout the construction stage, the BHPL's manpower will increase to about 181 staff to ensure effective management, supervision, coordination, and overall oversight of works. At peak construction, approximately 970 workers will be mobilized. Following completion of construction, an additional 84 personnel will be required for the operation and maintenance. The construction schedule for the major project components spans a total period of 57 months.

13.5.9.5 Workforce Characteristics

The required workforce for the Project will include a mix of unskilled and semiskilled construction labor as well as technicians, electricians, and engineers, especially for the tunneling, electromechanical works. About 32.5 percent of the construction workforce is expected to be unskilled labor. Taking into account the nature of the project workforce and characteristics of the labor force market in Bhutan, it is likely the workforce, especially the lower-skilled workers, will be predominantly male. It is possible that women could represent perhaps 5- 10 percent of the workforce, and those would likely be technical (e.g., engineering) and/or staff working in the operation offices and camps (maids, cooks, cleaners etc.).

13.5.9.6 Type of workers

Direct Workers: Direct workers for the construction of hydropower and associated facilities will include PMU team including BHPL staff's employees and who will be involved in project implementation. The staffs employed BHPP will fall in these categories. employees who were hired especially for the project and will be permanently based at project site office. Similarly, direct workers will include those from BHPP who are involved in HPP operations during and after construction.

Direct workers would also include independent consultants, who are specialized in certain disciplines (such as social safeguards and community relations). These consultants will be hired under individual contracts, on a part-time basis, with specific definitions of assigned tasks and responsibilities. At least one such direct worker is known, as described above: a half-time (or

more) ESHS specialist to be hired by BHPP to support the Project Management Consultant's supervision of contractors' ESHS performance. It would also include a third-party consultant who is hired to complete an audit of ESHS performance during the first year of construction and again just before project completion.

Contracted workers: Contracted workers for the rehabilitation works will include the PSC team acting as the Supervising Engineer. These on-site workers, three of whom are foreign professionals. The project will require various aspects expertise in the Project, including electromechanical works at the HPP, for geotechnical investigations and dam monitoring, for dam safety civil works (including the road), hydro mechanical equipment. The number of workers they will employ is not known Some of the contractors will engage multiple subcontractors but that will not be known until contractors are selected. The subcontractors' workforces will be also considered to be contracted workers. This category includes the following

- Staff of construction company appointed to undertake civil works and construction activities; and
- Specialist consultant firms engaged to prepare engineering designs, environmental and social assessments, develop training programs, materials or other technical inputs to Project activities

Migrant workers It is expected that the rehabilitation works will require a combination of local workers from nearby communities, workers from other parts of Bhutan, and possibly workers from other countries. The "internal migrants" would be semiskilled and skilled workers who already have experience working on similar projects in different parts of the country. Foreign "migrant" worker would be management and technical staff and possibly a few household staff (for cleaning, cooking, etc.). The number of migrant workers would depend on decisions made by contractors.

Primary supply workers – People employed or engaged by the primary suppliers. Primary suppliers will typically be required for civil works activities to be supported by the Project. They may include local suppliers of construction materials (e.g., aggregates, timber, cement, roofing iron, piping, electrical supplies, etc.) and equipment (e.g., machinery, tools, etc.). Where contractors source materials or equipment directly from primary suppliers on an ongoing basis, the workers engaged by such primary suppliers are deemed "primary supply workers". The number of primary supply workers associated with the Project will be estimated during the implementation phase. It is possible that there may not be any workers who fit the definition of primary supply workers, depending on supply and contracting arrangements.

Community workers – People employed or engaged in providing community labor. Community workers are not proposed to be Project-related activities and are not discussed further in these procedures

Table 86: Type of workers engaged and key risk and mitigation action

Worker's definition	Type of workers likely to be engaged	Key risks	Mitigation measures
Direct workers	Staffs engaged by BHPP, contractual staff engaged by the projectPSC	▪ Terms of employment (employment period, remuneration, tax and insurance payments etc.) not secured by contractual agreements. ▪ Workers suffer discrimination and lack of equal opportunity in employment. ▪ Risks of workplace accidents, or emergencies, i.e., occupational health and safety (OHS). ▪ Sexual Exploitation and Abuse and Sexual Harassment (SEAH), Gender Based Violence (GBV) and Violence Against Children (VAC) by workers to workers and community.	▪ Contractual terms to specify employment period, remuneration, tax and insurance payments etc. covered under BHPP I contracts. ▪ Procurement processes are transparent and reflect equal opportunity employment pursuant to the Bhutanese Labor Code. ▪ Verify that all personnel are aged 18 or over prior to contract signing. ▪ OHS measures to be implemented as set out in Appendix CESMP Management") for Direct workers ▪ Codes of Conduct (CoC), including SEAH are signed by all Direct workers ▪ All Direct workers receive CoC awareness training prior to undertaking Project activities. ▪ Provide access to Worker Grievance Mechanism (GM) (refer Section above) for any workplace, contractual or pay and working condition concerns including GBV, SEA and VAC.
Contracted workers	Contractors engaged for construction activities. Consultants engaged by a firm, contracted to provide technical advisory services.	▪ Terms of employment not secured by contractual agreements. ▪ Workers suffer discrimination and lack of equal opportunity in employment.	▪ Borrower to ensure contracts for construction workers include details on pay and working conditions in line with Bhutanese law and ADB requirements. ▪ Contractual terms for construction contractors to specify employment period contracts.to specify employment period, remuneration, tax and insurance payments ect, covered under the contract. ▪ BHPP to verify that all personnel are aged 18 or

Worker's definition	Type of workers likely to be engaged	Key risks	Mitigation measures
			over prior to contract signing. CoC, including SEAH, are signed by all Contracted workers ▪ All contracted workers receive CoC awareness training prior to undertaking Project activities. ▪ OHS measures to be implemented ▪ Ensure workers have access to Contractor GM for any workplace, contractual or pay and working condition concerns including SEAH, GBV and VAC
Primary supply workers	Quarry workers will be Primary Supply Workers.	▪ Non-compliance with child labor and minimum age; and forced labor provision of ADB requirement. ▪ Health of safety incident related to limited understanding and implementation of OHS requirements leading to injury or near miss.	▪ Minimum age, forced labor provisions and OHS measures to be implemented

13.5.9.7 Workers Grievance Redress Mechanism

A Workers' Grievance Redress Mechanism (WGRM) process will be implemented and maintained throughout the entire the project construction. It is a separate but complementary process to the Project Grievance Redress Mechanism which is used to record and manage grievances on the Project (e.g., by community members or other stakeholders). The mechanism will be hosted by the contractors. While each organization (employer) can develop and manage its own WGRM, they must reflect on the principles and process outlined in this section.

The WGRM is closely linked to the Gender, GBV-SEAH and Vulnerability Action Plan and sub-plan: Gender Based Violence – Sexual Exploitation and Abuse and Sexual Harassment (GBV-SEAH) Prevention and Response Action Plan, which described the specific GRM process for GBV-SEAH complaints. Grievances/cases related to the SEAH will be handled by this separate mechanism.

Key Principles

The process will be transparent and allow workers to express their concerns and file grievances.

- There will be no discrimination against those who express grievances.
- Grievances will be treated confidentially.
- Anonymous grievances will be treated equally as other grievances, whose origin is known.
- Workers will be informed of how their grievances are resolved. Resolution of anonymous grievances will be announced to the wider workforce.
- Management will treat grievances seriously and take timely and appropriate action in response.

A grievance is defined as a complaint by one or more workers, a workers' association, or an employer, relating to any matter concerning working conditions or the working environment arising at work or out of the workplace, as covered by the Labour and Employment Act of Bhutan 2007.

In Bhutan, a grievance procedure shall normally relate to the existing rights of workers under the Act and its Regulations, a written contract of employment, the Internal Service Rules, a collective bargaining agreement between workers and their employer, and rules established by custom and practice.

In any working environment it is essential for both employers and employees to be fully conversant with all aspects of disciplinary processes, the grievance redress procedures and the legal requirements and rights involved.

13.5.9.8 GRM Process

13.5.9.8.1 Direct Workers

According to National law an employer of an enterprise with 12 or more employees shall consult with the worker's association at the enterprise or, if there is no such association, the employee(s), prepare and implement a workplace grievance procedure for use at each workplace.

Labor Grievance Mechanism for *Direct Workers – Government/BHPL/BHPP* will use Dispute Resolution provisions embodied in their respective contracts based on the Labor and Employment Act and National public service regulations of Bhutan.

In summary for all grievances the first step will be the lodgment of the grievance (written or verbal) to the BHPP Project Manager, whom will within 2 weeks provide a response and seek resolution. If a resolution cannot be attained or agreed by the claimant, then the BHPP Project Manager may request the BHPL executive to review the complaint and seek a resolution OR it is registered and will be managed through the Bhutan National public service provisions. All illegal activities will be directly reported to the Police and/or security and managed accordingly.

13.5.9.8.2 Contracted Workers

All contracts will be required to include workers having access to a Grievance Mechanism and will use the principles outlined in Table below. All contracts as part of the government standard development process will be assessed by the PSC safeguard team, the safeguard team will ensure all contracts are aligned and compliant with ADB requirements.

13.5.9.8.3 Notification

During employee induction, *Direct Workers - Other* will be advised that there is a Labor Grievance Mechanism where workers can raise complaints and have them processed. Moreover, the BHPL safeguard team will provide contact information and provide a location where *Direct Worker - Other* and *Contracted Workers* can log their complaints. There will also be a notice at the BHPL at all times explaining the Labor Grievance Mechanism and providing contact details.

Table 87: Complaint resolution process

Step	Process
1.	Lodgment and initial informal process ▪ Managers and Workers are encouraged to use informal methods of resolving disagreements or disputes. ▪ If Workers have a reasonable grievance or complaint regarding their work or the people, they work with they should, wherever possible, start by talking it over with their manager. It may be possible to agree a solution informally between the Worker and the manager. ▪ If discussions with line managers fail to resolve the issue, it is still possible to pursue an informal approach without triggering a formal procedure. For example, an independent senior BHPL/or Government official could host an informal meeting or discussion. ▪ Grievances from new employees about recruitment practices will typically need to be made to the BHPL/ BHPP
2.	Formal grievance hearing ▪ If the matter is serious and/or the worker wishes to raise the matter formally, the Worker should set out the grievance in writing to the BHPL Project Manager and/or PSC Safeguard team. This submission should be factual and avoid language that is insulting or abusive. ▪ The BHPP Project Manager will then call the Worker and the Worker's Line Manager (or representative) to a meeting to discuss the Worker's grievance within a predetermined period of time [nominally 3 weeks] after receiving the complaint. ▪ The Worker has the right to be accompanied by a colleague at this meeting on request. ▪ After the meeting, the BHPP Project Manager will give the Worker minutes of the meeting signed by both parties and a decision in writing, within a predetermined period of time [nominally 4 weeks].

Step	Process
3.	Appeal to BHPL executive of Implementing Agency in which Worker is embedded ▪ If the Worker is not satisfied with the above decision, the worker may appeal the decision to the BHPL executive of the Implementing Agency in which the Worker is embedded. ▪ The executive will consult with the executive team in relation to the appeal on the Grievance. ▪ The executive will then call the Worker to a meeting to discuss the worker's grievance within a predetermined period of time [nominally 3 weeks] after receiving the complaint. ▪ The Worker has the right to be accompanied by a colleague at this meeting on request. ▪ After the meeting, the Secretary will give the Worker minutes of the meeting signed by both parties and a decision in writing, within a predetermined period of time [nominally 4 weeks]. ▪ The above decision is final within the terms of BHPL internal grievance mechanism which is deemed to cease at this stage. However, the Worker retains the ability to refer the complaint or grievance to the court for arbitration within the laws of Bhutan.
	Note: For grievances concerning workplace GBV, SEAH or VAC, survivors will be referred to appropriate SEAH Grievance Mechanism established in the project. This process will be reviewed and confirmed during Worker Code of Conduct awareness sessions, including disclosure options to ensure accountability, confidentiality and sensitivity.
Special provisions shall be applied for sensitive grievances, including complaints related to sexual exploitation, abuse and harassment (SEAH), gender-based violence, child protection, or other	

Step	Process
confidential matters. Such grievances shall be handled through confidential, survivor-centered procedures, with information shared strictly on a need-to-know basis and referral to appropriate support services where required.	

13.5.9.9 Responsibility of Project Engineers

- PSC will oblige to manage the E&S management system (including LMP) implementation by the Contractor/Primary Supplier in all Project sites. Ensuring compliance to the applicable ES Management System procedures as well as compliance with the applicable national regulations and ADB Safeguard requirements
- The PIC Consultant will involve in the development of Bidding Document for the Contractor selection, ensuring that the requirement of E&S system (including requirement in LMP, GBV protocol and OHS) for the Contractor are included
- The Consultant will report directly to E&S team by submitting monthly implementation report of ES Management System (including LMP).
- Develop ES management system (including LMP) work plan and organizational arrangement involving BHPP staff and Contractor/Primary Supplier worker as necessary (i.e. in grievance redress mechanism and/or emergency response organization).
- Review and provide input to the periodic ES management system (including LMP) implementation report submitted by the Contractor/Primary Supplier.
- Conduct routine site inspection to check on the actual implementation of ES management system (including LMP, GBV protocol, and OHS) by the Contractor/Primary Supplier in the Project sites

- Assist the ES Specialist in monitoring the implementation of GRM at the project sites. The implementation of GRM is under the responsibility of the ES Specialist (BHPL).

13.5.9.10 Contractor's minimum requirements in CESMP

The Contractor shall prepare a Labor Management Plan. This plan shall include at least the following minimum requirements:

- Document that the Contractor has adopted a Labor Policy that expressly prohibits child labor, forced labor, and discrimination of workers, and commits the Contractor to fair treatment of workers, equal opportunity, especially for women and people with disabilities, and the recognition of labor rights, including freedom of association and collective bargaining. The Contractor shall not make decisions relating to the employment or treatment of Contractor's Personnel on the basis of personal characteristics unrelated to inherent job requirements.
- The Contractor shall ensure that foreign workers are provided with the required residence visas and work permits. The Contractor will not retain their passport, work permit and other personal documents. At the completion of their employment, the Contractor shall be responsible for their return to their place of domicile.
- The Contractor, including its subcontractors, shall not employ or engage a child under the age of 14. No workers below the age of 17 will be allowed by the Contractor to undertake any work that is hazardous.
- The Contractor shall recognize workers' organizations as per law or any alternative forums which are constituted by workers protect their rights regarding working conditions and terms of employment and express their grievances on these issues.
- The Contractor shall not discriminate or retaliate against the Contractor's personnel who participate, or seek to participate, in workers organizations and collective bargaining or alternative mechanisms.
- The Contractor shall ensure gender neutral hiring advertisements (i.e., avoid terms such as workmen, linemen) and include that women are encouraged to apply).
- The Contractor will provide employment to women who have acquired new skills, such as machine operators, so that women receive a fair share of the employment opportunities in construction work.
- Source as much unskilled labor as possible from rural municipalities.
- Maximize local content in procurement (i.e., from local people and towns) whenever possible, and whenever project requirements are met.
- The Contractor will provide minimum wages as per applicable laws and shall inform all workers about any deduction applicable to their wages and the conditions of such deductions in accordance with the applicable laws during their recruitment process.
- The Contractors and subcontractors will keep a record of all workers engaged by them and make it available to the Project for periodic labor audits.
- The Contractor shall have a grievance mechanism to allow employees to raise workplace concerns. The Contractor's personnel shall be informed of the GRM at the time of engagement/contracting, and the measures put in place to protect them against any reprisal for its use. The GRM shall not impede access to other judicial or administrative remedies that might be available, or substitute for GRMs provided through collective agreements

The Contractor shall prepare a Long-Distance Transport and Logistics Protocol as a component of the Traffic Management Plan, specifically addressing bulk material haulage along the AH48 corridor from Phuentsholing to the Project site.

The Protocol shall address:

- Route designation and scheduling
- Vehicle standards
- Night-time restrictions
- Tshimalakha Hospital emergency access
- School zone protocol
- Community notification

13.5.9.11 Owner and Project Engineers Responsibility

BHPP will be responsible for the following actions:

- Review and approval of the Contractor's Labor Management Plan (LMP).
- Monitor Contractor performance

Appendix A Template on Contract for Code of Conduct

Template on Contract for Code of Conduct

We are the Contractor/Employer, [enter name of Contractor/Employer]. We have signed a contract with [BHPL] for [enter description of the Works]. These Works will be carried out at [enter the Site and other locations where the Works will be carried out]. Our contract/employment conditions require us to implement measures to address environmental and social risks related to the Works, including the risks of sexual exploitation and abuse, gender-based violence, and violence against children.

This Code of Conduct is part of our measures to deal with environmental and social risks related to the Works. It applies to all our staff, laborers and other employees at the Works Site or other places where the Works are being carried out. It also applies to the personnel of each subcontractor and any other personnel assisting us in the execution of the Works. All such persons are referred to as "Contractor/Employer's Personnel" and are subject to this Code of Conduct.

This Code of Conduct identifies the behavior that we require from all Contractor/Employer's Personnel.

Our workplace is an environment where unsafe, offensive, abusive or violent behavior will not be tolerated and where all persons should feel comfortable raising issues or concerns without fear of retaliation.

REQUIRED CONDUCT

Contractor/Employer's Personnel shall:

Carry out his/her duties competently and diligently;

1. Carry out his/her duties competently and diligently;
2. Comply with this Code of Conduct and all applicable laws, regulations and other requirements, including requirements to protect the health, safety and well-being of other Contractor's Personnel and any other person;
3. Maintain a safe working environment including by:
   a) ensuring that workplaces, machinery, equipment and processes under each person's control are safe and without risk to health;
   b) wearing required personal protective equipment;
   c) using appropriate measures relating to chemical, physical and biological substances and agents; and
   d) following applicable emergency operating procedures.
4. Report work situations that he/she believes are not safe or healthy and remove himself/herself from a work situation which he/she reasonably believes presents an imminent and danger to his/her life or health;
5. Treat other people with respect, and not discriminate against specific groups such as women, people with disabilities, migrant workers, or children;
6. Not engage in any form of sexual harassment including unwelcome sexual advances, requests for sexual favors, and other unwanted verbal or physical conduct of a sexual nature with other Contractor's or Employer's Personnel;
7. Not engage in Sexual Exploitation, which means any actual or attempted abuse of position of vulnerability, differential power or trust, for sexual purposes, including, but not limited to, profiting monetarily, socially or politically from the sexual exploitation of another. In ADB financed projects/operations, sexual exploitation occurs when access to or benefit from ADB financed Goods, Works, Consulting or Non- consulting services is used to extract sexual gain;
8. Not engage in Rape, which means physically forced or otherwise coerced penetration—even if slight —of the vagina, anus or mouth with a penis or other body part. It also includes penetration of the vagina or anus with an object. Rape includes marital or intimate partner rape and anal rape/sodomy. The attempt to do so is known as attempted rape. Rape of a person by two or more perpetrators is known as gang rape;
9. Not engage in Sexual Assault, which means any form of non-consensual sexual contact that does not result in or include penetration. Examples include: attempted rape, as well as unwanted kissing, fondling, or touching of genitalia, breasts, or buttocks, do not engage in any form of sexual activity with individuals under the age of 18, except in case of pre-existing marriage;
10. Complete relevant training courses that will be provided related to the environmental and social aspects of the Contract, including on health and safety matters, and Sexual Exploitation, and Sexual Assault (SEA);
11. Report violations of this Code of Conduct; and
    - Not retaliate against any person who reports violations of this Code of Conduct, whether to us or the Employer, or who makes use of the [Project Grievance Mechanism].

RAISING CONCERNS

If any person observes behavior that he/she believes may represent a violation of this Code of Conduct, or that otherwise concerns him/her, he/she should raise the issue promptly using the Project Grievance Mechanism process.

The person's identity will be kept confidential, unless reporting of allegations is mandated by the country law. Anonymous complaints or allegations may also be submitted and will be given all due and appropriate consideration. We take seriously all reports of possible misconduct and will investigate and take appropriate action. We will provide warm referrals to service providers that may help support the person who experienced the alleged incident, as appropriate.

There will be no retaliation against any person who raises a concern in good faith about any behavior prohibited by this Code of Conduct. Such retaliation would be a violation of this Code of Conduct.

CONSEQUENCES OF VIOLATING THE CODE OF CONDUCT

Any violation of this Code of Conduct by Contractor/Employer's Personnel may result in serious consequences, up to and including termination and possible referral to legal authorities.

FOR CONTRACTOR/EMPLOYER'S PERSONNEL:

I have received a copy of this Code of Conduct written in a language that I comprehend. I understand that if I have any questions about this Code of Conduct, I can contact [*enter name of Contractor/Employer's contact person with relevant experience in handling gender-based violence*] requesting an explanation.

Name of Contractor/Employer's Personnel: [insert name]

Signature:_____

Date: (day month year): _____

Appendix B Civil Works Contractor – Occupational Health and Safety Clause

General – Preparation of Contractor's OHS Procedures

The Contractor must prepare OHS procedures, to be cleared by the BHPL prior to works starting, which includes the following:

- Occupational Health and Safety Management procedures.
- Identification of staff responsible for, health and safety management, complaints management and reporting to the BHPL.
- Risk register documenting the site-specific and project specific risks.
- Training plan and training records relating to OHS.

Community and Worker Health and Safety

Site-specific mitigation to be inserted in the bid documents:

- The Contractor shall at all times implement all reasonable precautions to prevent and reduce accidents and injuries to staff and workers and protect the health and safety of the community.
- The Contractor shall prepare and implement an OHS management procedures commensurate with the identified health and safety hazards at the construction site/s and it shall include activities related to construction (such as the transportation of materials and working in road easements).
- The Contractor shall at all times provide and maintain construction plant, equipment and systems of work that are safe and without risks to health. This shall include maintaining equipment, engines, and related electrical installations in good working order; maintaining a clean and tidy workspace; providing safe and exclusion barriers (e.g., guards and rails), signage, and lighting; providing work site rules, safe working procedures and allocating appropriate places to carry out the work.
- The Contractor shall provide, at his/her own expense, the protective clothing and safety equipment (Personal Protective Equipment - PPE) to all staff and labor engaged on the Works to the satisfaction of the PIU. Such clothing and equipment shall include, as a minimum:
  - High visibility vests for workers directing traffic;
  - Protective boots, gloves and hard hat for the workforce undertaking excavation works; and
  - Sun protection (e.g., hat, long sleeved shirt/pants etc).

If the Contractor fails to provide such clothing and equipment, the PSC has the right to issue a stop work notice until the Contractor has provided the suitable equipment.

- The Contractor shall, before commencing work, conduct an induction course with all relevant workers on environmental management and safety and health at the site. The information and training shall be on the site and have duration of at least two hours.
- The Contractor shall prepare and implement a Traffic Management Plan (TMP) to ensure that any traffic and/or pedestrian hazards caused by the works are adequately managed. Special emphasis needs to be placed on the management of pedestrian movements and

access through all work sites, including considerations for the elderly and youth (i.e., children).

- The Contractor shall adopt the following for workers working at height, in addition to Bhutan and state regulations:
- The area around which elevated work is taking place should be barricaded to prevent unauthorized access. Working under other personnel should be avoided;
- Hoisting and lifting equipment should be rated and maintained and operators trained in their use. Elevating platforms should be maintained and operated according to established safety procedures that include such aspects as equipment and use of fall protection measures (e.g., railings), movement of location only when the lift is in a retracted position, repair by qualified individuals, and the use of effective locks to avoid unauthorized use by untrained individuals;
- Ladders should be used according to pre-established safety procedures including proper placement, climbing, standing, and the use of extensions, as outlined in the Contractors OHS procedures.
- Implementation of a fall protection program that includes training in climbing techniques and use of fall protection measures; inspection, maintenance, and replacement of fall protection equipment; and rescue of fall-arrested workers, among others; and
- Establishment of criteria for use of 100 percent fall protection (typically when working over 2 meters (m) above the working surface, but sometimes extended to 7 m, depending on the activity).
- The Contractor shall implement confined space entry management procedures where workers will be entering confined spaces (if required), which are to be outlined in the Contractors OHS procedures.

Worker Accommodation

All workers shall be provided with safe and healthy accommodation, with potable drinking supply, running water, septic tank or reticulated wastewater collection and treatment, separate sleeping quarters (with separation of washrooms, bedrooms and toilets for men and women), and access to recreation areas / facilities. No new worker's camps or worker accommodation facilities will be constructed (permanently or temporarily) for the workforce.

Worker Code of Conduct

All workers shall be required to sign and adhere to a Code of Conduct CoC) prepared by the Contractor, relating to worker behavior to avoid harm to community members, including reference to Gender Based Violence (GBV), Sexual Exploitation and Abuse and Sexual Harassment (SEAH). Training will be provided to outline appropriate behavior and implications for nonconformance and general awareness of SEAH, along with general awareness of the Grievance Mechanism (GM) for SEAH.

13.5.10 Alternative fuel and energy supply plan for worker camps

During peak construction, the BHPP will host approximately 970 contractor personnel and 181 BHPL staff, housed primarily in Labour Camp-1 (7.41 acres near Bunakha village) and Labour Camp-2 (1.24 acres near Chanachen village).

Winters in this Himalayan region are exceptionally cold. Without strict provisioning and management, a workforce of this size will naturally resort to harvesting the abundant dry wood from the surrounding dense forests for cooking, water heating, and space heating. Left unmanaged, this will lead to severe localized deforestation, increased risk of devastating forest fires, and hazardous indoor air pollution (particulate matter and CO) within the worker dormitories. To prevent these impacts and align with Bhutan's stringent environmental conservation mandates, the reliance on forest wood by any project personnel is strictly prohibited.

13.5.10.1 Environmental and Health Risks

If the EPC Contractor fails to provide reliable alternative fuels, the following severe impacts will occur:

Deforestation & Biodiversity Loss: Rapid depletion of surrounding forest cover (especially in the biologically rich corridors near Bunakha and Chanachen), destroying habitats and degrading the local carbon sink.

Forest Fire Hazard: Uncontrolled gathering of dry wood and open-flame campfires drastically increase the risk of uncontrolled forest fires, especially during the dry winter and pre-monsoon windy seasons.

Indoor Air Pollution: Burning wood inside unventilated worker tents or dormitories causes acute respiratory illnesses (CO poisoning, asthma) and violates basic occupational health and safety (OHS) standards.

Community Friction: Competition for local forest resources will create immediate social conflict between the migrant workforce and the host communities of Chanachen and Bunakha, who rely on these forests for sustainable timber and non-timber forest products (NTFPs).

13.5.10.2 Mandatory Energy Provisions (Contractor Obligations)

The provision of alternative fuels is not an optional "good practice"; it is a mandatory environmental safeguard. The Contractor must provision reliable, clean alternative energy systems for all labour camps as part of their Construction Environmental and Social Management Plan (C-ESMP).

Centralized Messing and Cooking (LPG & Electricity): Individual cooking inside worker tents or dormitories is strictly banned due to extreme fire hazards and energy inefficiency. The Contractor must establish centralized, commercial-scale mess kitchens. These kitchens must be powered entirely by commercial Liquefied Petroleum Gas (LPG) or industrial electric stoves (utilizing the Project's grid-connected construction power).

Space Heating: To prevent workers from using wood for space during the freezing winter months, the Contractor must provide safe, standardized electric room heaters (with auto-shutoff safety features) in all worker dormitories, powered by the camp's electrical grid.

Solar Water Heating (Thermal): To drastically reduce the electrical base-load and eliminate the need to heat bathing water over wood fires, the Contractor must install roof-mounted Solar

Thermal Water Heaters on all worker ablution blocks. This is a highly proven, scalable, and cost-effective renewable technology in Bhutan.

Solar PV for Camp Lighting: While the camps will be connected to the main construction power grid, the Contractor must utilize standalone Solar Photovoltaic (PV) streetlights for camp pathways, perimeter security, and emergency lighting, ensuring safety during grid outages without relying on polluting diesel generators.

13.5.10.3 Implementation, Logistics, and Safety Considerations

Logistics & Supply Chain: The Contractor is solely legally and financially responsible for maintaining an uninterrupted supply chain of LPG cylinders to the remote camps. An adequate, securely stored buffer stock must be maintained on-site to prevent fuel shortages that might drive workers back to the forest.

Health & Safety: Transitioning from firewood to LPG and electricity eliminates hazardous indoor smoke. However, the Contractor must install proper mechanical ventilation and commercial gas-leak detectors in all mess kitchens. All electrical wiring for winter heaters must meet industrial safety standards (to prevent electrical fires) and be inspected monthly by a certified electrician.

Zero-Tolerance Policy: The Contractor must enforce a strict "Zero-Tolerance" policy against illegal logging, tree lopping, and firewood collection within the mandatory Worker Code of Conduct. Any worker caught harvesting forest wood must face immediate disciplinary action.

13.5.10.4 Monitoring and Compliance Program

ESHS and the Project Supervision Consultant (PSC) will enforce the following monitoring measures:

Table 88: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	"Camp Energy & Fuel Supply Method Statement" approved	Pre-mobilization	Project Office	Contractor / PSC
Fuel Supply Audits	Review of LPG procurement logs vs. workforce population needs	Weekly	Camp Stores / Mess Kitchens	PSC
Unannounced Camp Inspections	Confiscation of unauthorized firewood, electric coils, or open-flame stoves	Weekly	Labour Camps 1 & 2	PSC EHS Team
Forest Edge Patrols	Signs of illegal tree cutting, lopping, or hidden firewood caches	Bi-Weekly	Forest boundaries around Bunakha & Chanachen	Contractor Security / PSC

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
LPG Storage Safety	Gas leak detectors functional; ventilation clear; fire extinguishers charged	Monthly	Central LPG Storage Depots	PSC
Electrical Load & Safety Audit	Safe wiring of winter heaters; functionality of Solar Thermal units	Monthly (Winter)	Labour Camps 1 & 2	Contractor / PSC
Compliance Reporting	Monthly EHS reports detailing fuel consumption and any firewood disciplinary actions	Monthly	All Camps	Contractor / ESHS

13.5.10.5 Resources Required

Energy Infrastructure: Commercial-grade LPG stoves and centralized kitchen equipment; high-capacity Solar Thermal Water Heating units; Solar PV streetlights; standardized, fire-safe electric room heaters.

Storage & Safety: Bunded, ventilated, and caged outdoor storage depots for bulk LPG cylinders; commercial gas-leak detectors; high-capacity fire extinguishers.

Personnel: Dedicated Camp Managers to oversee fuel distribution; licensed electricians for camp maintenance; camp security guards for forest edge patrols.

Supply Contracts: Reliable, long-term procurement contracts with national LPG distributors to ensure uninterrupted winter supply.

13.5.10.6 Institutional Arrangements

EPC Contractor: Legally and financially responsible for procuring all LPG, installing solar thermal units, operating the centralized mess, and enforcing the Zero-Tolerance firewood policy.

PSC (Supervision Consultants): Responsible for conducting weekly unannounced camp inspections, auditing fuel logs, and issuing immediate financial penalties if workers are found harvesting forest wood or living without adequate heating provisions.

ESHS (Environment Social Health and Safety Unit): Oversees overall compliance and handles any grievances from local communities regarding workers trespassing into community forests.

Department of Forests and Park Services (DoFPS): Conducts independent patrols of the surrounding state forests and holds the authority to prosecute the Contractor under national law for illegal logging or NTFP extraction.

13.5.11 Soil conservation

The BHPP will fundamentally alter the local topography. The construction phase requires massive land modification, including 4.30 million m³ of excavation for the dam complex alone, generating a total of 5.65 million m³ of excavated material requiring safe disposal across 129.85

hectares of Muck Disposal (MD) sites. In total, the project footprint will affect approximately 1139.87 acres of land.

The 2025 physical baseline survey confirmed that soils in the project area are predominantly loamy, highly rich in organic carbon (>0.95%), and structurally fragile when exposed on steep slopes (e.g., the Chanachen gorge). Furthermore, the Wangchhu River is highly sensitive to suspended sediment loads. This Soil Conservation Plan mandates the integration of structural engineering and bio-engineering techniques to safeguard catchment integrity, prevent catastrophic slope failures, and minimize sediment transport into the river systems.

13.5.11.1 Environmental Risks

Without rigorous, engineered soil conservation, the project's mass earthworks will trigger the following severe impacts:

- Land Degradation & Topsoil Loss: Uncontrolled excavation will permanently destroy the highly fertile biological topsoil layer. Exposed steep slopes at the dam abutments and INRQ-3 quarry will rapidly erode, forming deep gullies and triggering localized landslides.
- Water Quality & Aquatic Ecosystems: Runoff from massive earthworks and muck dumps (MD-1, MD-2, MD-4) will wash directly into the Wangchhu River. This will cause severe spikes in Total Suspended Solids (TSS) and turbidity, smothering benthic habitats and disrupting the spawning grounds of native fish (Schizothorax richardsonii).
- Reservoir Sedimentation: Upstream catchment erosion will accelerate sediment inflow into the newly formed reservoir. Unmanaged, this will exceed the estimated 0.34 mm/year baseline sediment accumulation, rapidly depleting the 250.62 million m^3 live storage capacity and threatening turbine efficiency.
- Infrastructure Damage: Uncontrolled runoff will scour the newly upgraded 6.15 km of access roads (including the 5.5 km Chanachen farm road), undercutting retaining walls and destroying road base materials.

13.5.11.2 Mandatory Mitigation Measures (Phase-Wise)

Implementation of these measures is the strict responsibility of the EPC Contractor, subject to enforcement by the PSC and ESHS.

13.5.11.2.1 Pre-Construction Phase (Site Preparation)

- Perimeter Drainage & Sediment Traps: Before any bulk earthworks or tree felling begins, the Contractor must install catchwater drains around the uphill perimeter of all planned excavation zones and Muck Disposal (MD) sites. Temporary sediment traps and silt fences must be installed at the lowest topographical points to capture initial runoff.
- Muck Disposal (MD) Toe Walls: The foundational gabion or concrete toe-walls for MD-1, MD-2, and MD-4 must be fully constructed to their initial design heights prior to the dumping of any muck.

13.5.11.2.2 Construction Phase (Active Earthworks & Stabilization)

- Strict Topsoil Preservation: The highly fertile top 300 mm of organic soil must be systematically stripped from all footprints (camps, dam axis, powerhouse, quarries) prior to

deep excavation. This must be safely stockpiled, covered, and seeded with cover crops to preserve the soil microbiome for future site restoration.

- Engineered Slope Stabilization:
  - Dam Abutments & Portals: Deep-cut rock slopes must be immediately stabilized using targeted rock bolts (4m to 6m), wire mesh, and shotcrete to prevent rockfalls and mass wasting.
  - Soil Slopes: Exposed soil slopes along access roads and quarry benches must be stabilized using terracing/benching and immediate bio-engineering (e.g., coir matting pinned with fast-growing *Vetiver* grass or native bamboo).
- Runoff & Sediment Management:
  - Multi-chambered sedimentation ponds must be constructed at the runoff exit points of the batching plants, powerhouse excavation, and all MD sites. Water must meet national TSS effluent standards before discharge into the Wangchhu River.
  - Bare soil surfaces left inactive for more than 14 days must be protected using geotextile mats, jute covers, or thick organic mulching to prevent rain-splash erosion.
- Access Road Controls: All unpaved internal haul roads must be properly cambered with lined side-drains and cross-culverts to prevent gully erosion. A strict 20 km/h speed limit must be enforced to reduce dust generation and road-surface degradation.

13.5.11.2.3 Operation Phase (Long-Term Management by BHPL

- Catchment Area Treatment (CAT): BHPLmust implement the mandatory CAT Plan in the upstream Wangchhu basin. This includes extensive afforestation, agroforestry, and the construction of contour bunds and check dams in degraded micro-catchments to actively reduce the baseline sediment load entering the reservoir.
- Reservoir Rim & Sediment Flushing:
  - The 17.25 km reservoir shoreline must be protected against wave-induced erosion using targeted riprap, gabions, and dense vegetative buffers.
  - BHPL will conduct controlled sediment flushing during the high-flow monsoon season utilizing the dam's mid-level outlets (EL 1915 m) to maintain live storage capacity and replenish downstream sediment regimes.
- Community Engagement: Train local upstream communities in soil conservation farming practices (e.g., contour ploughing, vegetative bunding) to ensure the long-term success of the CAT Plan.

13.5.11.2.4 Decommissioning phase

- Removal of Temporary Structures: Coffer dams (EL 1890 m and 1857 m) must be dismantled systematically during low-flow periods, with turbidity curtains deployed in the river to prevent massive sediment plumes.
- Site De-compaction & Revegetation: All temporary construction infrastructure, labour camps, and laydown areas must be mechanically de-compacted. Preserved topsoil must be replaced, and the areas fully revegetated to restore natural water infiltration rates and prevent long-term post-project erosion.

Table 89: Monitoring and Compliance Program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility

C-ESMP Approval	Detailed Erosion & Sediment Control Plan approved	Pre-construction	Project Office	Contractor / PSC
Slope Stability Audits	Signs of slumping, tension cracks, functionality of rock bolts/gabions	Weekly (Monsoon); Monthly (Dry)	Dam abutments, INRQ-3, MD sites	Contractor / PSC
Sediment Runoff (Water Quality)	Total Suspended Solids (TSS mg/L), Turbidity (NTU)	Weekly during active earthworks	SW-02 (Dam Downstream), SW-09	SC
Topsoil Stockpile Checks	Stockpile height, vegetative cover, silt fence integrity	Monthly	All designated stockpile areas	PSC
Revegetation & Bio-engineering	Percentage cover, species survival rate (>80% required)	Annually	Quarry benches, MD sites, road slopes	ESHS/ PSC
Reservoir Sedimentation	Bathymetric surveys to measure sediment accumulation rate	Every 5 Years (Operation)	Bunakha Reservoir	BHPL

13.5.11.3 Resources Required

- Erosion Control Materials: Geotextile mats, jute/coir erosion control blankets, heavy-duty silt fencing, gabion wire baskets, and organic mulching materials.
- Vegetation Materials: Seeds and seedlings of deep-rooting native grasses, native shrub/tree saplings (as per Compensatory Afforestation Plan), and bio-fencing materials.
- Equipment: Hydro-seeding machines, mechanical compactors, excavators, water tankers for dust suppression, and drones for GIS-based aerial erosion mapping.
- Monitoring Tools: Real-time turbidity meters, suspended sediment samplers, and GPS surveying equipment for slope movement detection.
- Personnel: Specialized Geotechnical Engineers, Bio-engineering Specialists, and dedicated field environmental monitors.

13.5.11.4 Institutional Arrangements

- EPC Contractor: Legally responsible for executing all soil conservation measures, building MD toe-walls before dumping, installing sediment ponds, and maintaining all temporary drainage systems.
- PSC (Supervision Consultants): Responsible for approving structural slope designs, conducting weekly erosion control audits, monitoring river TSS levels, and halting works if severe uncontrolled runoff occurs.
- DGPC (Environmental Management Unit): Oversees the implementation of the long-term CAT Plan, manages reservoir rim stability, and coordinates with local agricultural extensions for community soil conservation training.
- Department of Forests and Park Services (DoFPS) / Department of Water (DoW): Provide regulatory guidance on afforestation species and monitor compliance with national sediment and water quality standards.

13.5.12 Land restoration and landscaping plan

Hydropower projects disturb large tracts of land through mass excavation, muck disposal, reservoir creation, and infrastructure development. For the BHPP, these activities will permanently and temporarily affect approximately 1139.87 acres of land.

The 2025 physical baseline survey confirmed that the soils in these disturbance zones are pristine, predominantly loamy, and highly rich in organic carbon (>0.95%). Without strict management, mass earthworks will destroy this fertile biological layer, destabilize slopes, and cause severe sedimentation in the Wangchhu River.

This Land Restoration and Landscaping Plan establishes the mandatory engineering and ecological interventions required to rehabilitate disturbed areas, restore ecological balance, and harmonize the project footprint with its natural surroundings.

13.5.12.1 Environmental Impacts

Without targeted restoration, the project's earthworks will trigger the following cascading impacts:

Land & Soil Degradation: Severe soil erosion and the permanent loss of fertile topsoil from exposed surfaces (dam abutments, INRQ 1-3 quarry sites, and MD areas). The heavy staging of machinery will cause deep soil compaction, destroying natural porosity and making the land unsuitable for post-project community use.

Hydrology & Water Quality: Accelerated runoff will increase sedimentation in the Wangchhu River, degrading water quality and threatening aquatic species (*Schizothorax richardsonii*). Unrestored slopes will alter natural drainage, leading to localized waterlogging or flash flooding.

Biodiversity Loss: The clearing of approximately 829.32 hectares of forest will fragment wildlife corridors and reduce the ecosystem's resilience to climate change.

Infrastructure & Aesthetic Risks: Un-stabilized slopes threaten the structural integrity of the newly upgraded 6.15 km access roads and 5.5 km Chanachen farm road. Visually, unrestored quarries and muck dumps will permanently scar the landscape, negatively impacting the aesthetic value of nearby heritage sites (Bunakha Lhakhang, Lobnekha Heritage Village).

13.5.12.2 Mandatory Mitigation Measures (Phase-Wise)

To ensure clear contractual accountability, mitigation measures are divided by project phase. Implementation is the responsibility of the EPC Contractor, while Monitoring is the responsibility of the PSC and ESHS.

Pre-Construction Phase (Site Preparation)

Strict Footprint Demarcation: The Contractor must physically peg and fence the absolute minimum footprint required for camps, access roads, and laydown areas. Unauthorized clearing outside these boundaries is strictly prohibited.

Mandatory Topsoil Protocol: Before any bulk excavation begins, the highly fertile top 300 mm of organic soil must be systematically stripped. This topsoil must be stockpiled in designated,

well-drained areas, bounded by silt fencing, restricted to a maximum height of 2 meters (to prevent anoxic compaction), and immediately seeded with fast-growing native cover crops to preserve the soil microbiome.

Erosion Control Planning: Temporary erosion controls (silt fences, sediment traps, check dams) must be fully installed at the toe of all planned Muck Disposal sites (MD-1, MD-2, MD-4) before any muck is deposited.

Construction Phase (Progressive Rehabilitation)

Concurrent Muck Rehabilitation (MD Sites): The Contractor is prohibited from waiting until the end of the project to rehabilitate the 129.85 hectares of muck disposal sites. As soon as a dumping terrace reaches its final design grade, it must be immediately levelled, capped with the preserved topsoil, and stabilized using bio-engineering techniques (e.g., hydro-seeding, coir matting, and native shrub planting).

Quarry Bench Stabilization: Following extraction at INRQ-3 and other quarries, exhausted benches must be reshaped to stable contours and progressively planted with native species as per the Quarry Restoration Plan to reduce dust wind-whip.

Green Buffers: Dense vegetative buffer screens of native trees must be established between the active crushing/batching plants and the Chanachen village to act as natural dust filters and acoustic dampeners.

Dam and Powerhouse Vicinity: The areas surrounding the 85.5m × 58.2m powerhouse and 499m dam crest must be progressively landscaped using soil-binding, hardy ornamental species to prevent localized runoff.

Operation Phase (Long-Term Integration)

Reservoir Periphery Landscaping (ESHS): Establish a protective green belt of native, water-tolerant tree species around the 17.25 km Full Reservoir Level (FRL) margin to stabilize the banks against wave-action erosion and create community recreational zones.

Catchment Area Restoration: Execute the Catchment Area Treatment (CAT) Plan, utilizing contour bunding and agroforestry in the upstream degraded zones to reduce long-term sediment inflow into the reservoir.

Biodiversity Corridors: Establish vegetative corridors to reconnect habitats fragmented by the reservoir, specifically linking areas north and south of the water body.

Decommissioning Phase (Site Handover)

De-compaction of Temporary Sites: All temporary staging areas, Labour Camps (1 & 2), and decommissioned batching plant footprints must be mechanically ripped/scarified to a minimum depth of 400 mm to alleviate severe soil compaction and restore natural drainage.

Topsoil Replacement: Preserved organic topsoil must be uniformly spread over the de-compacted areas and replanted to match or exceed pre-project ecological conditions.

Infrastructure Removal: All construction debris and contaminated soils (e.g., hydrocarbon spills at workshop sites) must be safely excavated and disposed of prior to final landscaping.

13.5.12.3 Monitoring and Compliance Program

Land restoration compliance is tied directly to the Contractor's financial milestones. The release of final retention money shall be contingent upon the successful ecological restoration of all temporary sites.

Table 90: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	Submission of detailed Topsoil & Revegetation Method Statement	Pre-construction	Project-wide	Contractor / PSC / ESHS
Topsoil Audits	Volume stripped, stockpile height (<2m), vegetative cover, silt fencing integrity	Monthly during excavation	Dam site, quarries, camps, MD sites	PSC
Revegetation Success	Minimum 80% plant survival rate; vegetation coverage percentage	Quarterly (Construction); Annually (Operation)	MD sites, quarries, access roads	Contractor / PSC
Slope Stability	Absence of erosion gullies, landslide occurrence, settlement of toe walls	Weekly (Monsoon); Monthly (Dry season)	Dam abutments, MD sites, reservoir rim	Contractor / PSC
Sediment Control	Turbidity (NTU), TSS (mg/L) at downstream receptors	Weekly during active earthworks	SW-2 (Dam downstream), SW-9 (Nayakha Chhu)	PSC
Site Handover Certification	Formal "Land Restoration Sign-Off" confirming de-compaction and revegetation	Post-decommissioning	All temporary leased/utilized lands	ESHS/ Local Gewog

13.5.12.4 Resources Required

Planting Materials: Native grass seeds, native shrub/tree saplings (sourced locally to provide community livelihood benefits), organic compost, and bamboo for bio-fencing.

Structural Materials: Geo-textiles (coir/jute erosion control blankets), gabion baskets, and stone aggregates.

Equipment: mechanical rippers/scarifiers for soil de-compaction, dozers, and dedicated water sprinklers for dry-season irrigation.

Personnel: The Contractor must employ or subcontract a qualified Bio-engineering/Revegetation Specialist to oversee the ecological restoration of the MD sites and quarry benches.

13.5.12.5 Institutional Arrangements

EPC Contractor: Responsible for funding and executing all restoration measures, stripping topsoil, concurrent rehabilitation of MD sites, and ensuring an 80% plant survival rate for three years post-planting.

PSC (Project Management & Supervision Consultants): Responsible for approving the Contractor's method statements, conducting weekly field inspections, auditing topsoil stockpiles, and recommending financial penalties for non-compliance.

ESHS (Environmental Social Health and Safety Unit): Provides overall project oversight, coordinates with local communities for post-project land use, and issues final compliance sign-offs in coordination with regulatory agencies.

Regulatory Agencies (DECC, DoFPS, DoW): Conduct periodic compliance monitoring and review statutory environmental reports.

13.5.13 Mitigation measures for downstream siltation

To mitigate downstream siltation resulting from reservoir sediment accumulation, scheduled sediment flushing operations will be carried out during the early monsoon and post-monsoon periods. These flushing events are strategically timed to coincide with the monsoon season, when the Wangchu River experiences significantly elevated flow volumes and velocities, thereby providing sufficient energy to effectively transport and disperse the accumulated sediment load downstream without causing disproportionate depositional impacts. The high river discharge during this period naturally assists in diluting and mobilizing the flushed sediment, reducing the risk of localized siltation in the downstream reach. This approach is consistent with the established operational practices already adopted by the downstream Chhukha Hydropower Plant (CHP) and Tala Hydropower Plant (THP), ensuring a coordinated and basin-wide sediment management strategy along the Wangchu River cascade.

13.5.13.1 Sediment Management Measures in catchment area

Following measures have been identified to address sediment sources, transport, and deposition across the Wangchhu catchment, integrating upstream watershed management with reservoir operations and downstream cascade coordination.

Sediment Management Measures

Measures	Objective	Key Actions / Notes
Catchment stabilization	Reduce erosion at source	Bioengineering, slope terracing, gully plugs, erosion-control structures in high-yield sub-catchments
Afforestation and plantation	Increase vegetative cover	Native species plantation, riparian buffers, controlled grazing to reduce sheet and rill erosion

Check dams on major tributaries	Trap coarse sediment upstream	Series of check dams, silt traps, gabion barriers on key tributaries feeding the reservoir
Stream bank and gully protection	Stabilize eroding channels	Gabion walls, brushwood structures, toe protection, bio-engineering on active gullies
Landslide and slope failure management	Prevent large sediment pulses	Mapping hotspots, drainage trenches, retaining structures, slope regrading, vegetation control
Reservoir rim protection	Prevent rim erosion during drawdown	Rock bolting, shotcrete, toe walls, drainage to stabilize banks affected by annual drawdown cycle
Sediment flushing and routing	Manage deposited sediment	Monsoon flushing, drawdown flushing where feasible, sediment pass-through operations coordinated with CHP and THP
Low-level outlet optimization	Ensure sediment evacuation capacity	Adequate discharge capacity, low invert level, operational protocols for peak sediment periods
Sediment monitoring system	Enable adaptive management	Real-time turbidity sensors, suspended sediment concentration (SSC) monitoring, rainfall triggers, upstream slope-activity alerts
Community-based watershed management	Long-term catchment protection	Local stewardship for forest protection, grazing control, check-dam maintenance, ESMP integration

Further, BHPL shall prepare and implement a comprehensive basin wide Sediment Management Plan prior to commissioning, covering the following:

- Reservoir sediment management
- Basin-wide sediment balance monitoring
- Climate-driven sediment risk management

Sediment flushing operations shall be coordinated with the E-flow Management Plan.

Regular sediment sampling and bathymetric surveys are identified as prioritised and continued activities throughout the operational life of the Project in DPR,2026. Sediment monitoring and research on sediment transport at upstream gauging locations within the Wangchhu catchment shall be conducted to assess basin-scale sediment movement processes, inform adaptive reservoir operation, and update the sediment mass balance on a periodic basis.

13.5.14 Waste water management plan

The BHPP will generate significant volumes of wastewater during both the construction and operational phases. During peak construction, the site will host approximately 970 contractor personnel and 181 BHPL staff, primarily concentrated at Labour Camp-1 (near Bunakha village) and Labour Camp-2 (below Chanachen village). In addition to domestic sewage, industrial wastewater will be continuously generated from the RCC/CVC batching plants, heavy machinery workshops, and underground excavation sites (tunnel seepage).

The 2025 baseline surveys established that the Wangchhu River possesses a pristine chemical baseline ("zero-tolerance" for industrial pollutants), while community drinking water springs (SW-05, SW-09, SW-10) are already vulnerable to bacteriological contamination. This Wastewater Management Plan establishes the mandatory engineering and ecological interventions required to treat all domestic and industrial effluents, ensuring strict compliance with Bhutanese Environmental Standards (ES 2020), ADB SPS (2009), and IFC General EHS Guidelines.

13.5.14.1 Environmental and Health Risks

Without strict wastewater management, the project presents the following severe risks:

Industrial Chemical Contamination: Wastewater from the RCC/CVC batching plants is highly alkaline (high pH) and laden with cementitious solids. Runoff from main workshops contains toxic hydrocarbons and heavy metals. Direct discharge into the Wangchhu River will instantly cause acute toxicity to aquatic life (*Schizothorax richardsonii*) and violate the pristine chemical baseline.

Bacteriological Pollution & Public Health: The discharge of untreated raw sewage from labour camps will introduce massive nutrient and pathogen loads (faecal coliforms) into the watershed. This threatens down-gradient community drinking water sources (e.g., SW-09 Nayakha Chhu, SW-10 Chanachen Spring) and risks outbreaks of cholera, dysentery, and hepatitis among both workers and villagers.

Tunnelling Effluent: Seepage water pumped from the 360 m powerhouse access tunnel and diversion tunnels contains extremely high Total Suspended Solids (TSS) and residual nitrates from blasting explosives, which can cause severe localized eutrophication and turbidity spikes if discharged untreated.

13.5.14.2 Mandatory Mitigation Measures (Phase-Wise)

Implementation of these measures is the strict responsibility of the EPC Contractor during construction and BHPL during operation, subject to enforcement by the PSC and regulatory authorities.

Pre-Construction Phase (Infrastructure Planning)

Treatment Infrastructure Siting: The Contractor must design and finalize the locations of all Septic Tanks, , and sedimentation basins prior to mobilization. A mandatory minimum buffer of 50 meters must be maintained between any wastewater treatment/discharge point and community water sources.

Drainage Layouts: Separate drainage networks must be designed for stormwater (clean runoff) and industrial/domestic wastewater (dirty runoff) to prevent the hydraulic overloading of treatment plants during the monsoon.

Construction Phase (Active Wastewater Treatment)

Domestic Wastewater (Labour Camps & Offices):

- The discharge of raw or partially treated sewage is strictly prohibited.

- The Contractor must install STPs for Labour Camps 1 & 2.
- Treated effluent must meet Bhutan ES 2020 standards before environmental discharge. Where feasible, treated water should be recycled for site dust suppression.

Industrial Wastewater (Batching Plants & Crushers):

- Batching plants must operate on a Zero Liquid Discharge (ZLD) principle. All concrete wash-water must be routed through an automated pH neutralization unit (using acid dosing or CO_2) to achieve a pH of 6.5–8.5. The neutralized water must pass through multi-stage settling pits and be recycled for aggregate washing.

Hydrocarbon Wastewater (Workshops):

- All vehicle wash bays and maintenance workshops must be constructed on impermeable concrete pads. Drainage from these pads must pass through standardized API Oil-Water Separators to remove hydrocarbons and grease before discharge.

Tunnel and Excavation Effluent:

- Water pumped from underground excavations must be routed through multi-chambered desilting basins to allow fine sediments to settle. Flocculants may be used if TSS remains above permissible discharge limits.

Secondary Containment:

- All bulk chemical, fuel, and liquid admixture storage tanks must be placed within concrete bunds capable of holding 110% of the largest tank's volume to contain catastrophic leaks.

Operation Phase (Long-Term Management by BHPL

Permanent Colony Domestic Wastewater: BHPL must operate and maintain the permanent STP servicing the operational staff colony (84 personnel) and administrative offices. Periodic desludging must be conducted by authorized municipal vacuum trucks.

Powerhouse Effluents:

- Cooling water and floor drainage from the 180 MW powerhouse must pass through an industrial Effluent Treatment Plant (ETP) equipped with oil-skimmers and separators before outfall into the Wangchhu River tailrace.

Spill Response: BHPL must maintain operational emergency spill kits (absorbent booms, pads) at the powerhouse and switchyard to rapidly contain any accidental transformer oil or hydraulic fluid leaks.

Decommissioning Phase

Controlled STP Decommissioning: Temporary camp septic tanks must be kept fully operational until the workforce is completely demobilized. Prior to dismantling, all sludge and residual wastewater must be safely pumped out and transported to an authorized municipal treatment facility.

Hazardous Washdown: The dismantling of batching plants, workshops, and fuel depots must include controlled washdowns. Wash-water must be captured and treated as hazardous liquid waste; it cannot be allowed to infiltrate the underlying soil

13.5.14.3 Monitoring and Compliance Program

Table 91: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	Detailed Wastewater Management & ZLD Plan approved	Pre-construction	Project Office	Contractor / PSC
STP Effluent Quality	BOD, COD, TSS, pH, Faecal Coliforms	Weekly	Camp STP Outlets	Contractor / PSC
Industrial Effluent (Workshops)	Oil & Grease (mg/L), pH, TSS	Weekly	API Separator Outlets	Contractor / PSC
Batching Plant ZLD Check	Visual confirmation of no discharge; pH levels of recycled water	Weekly	RCC/CVC Batching Plants	PSC
Tunnel Seepage Quality	TSS (mg/L), Nitrates, pH	Weekly	Tunnel Portal Settling Basins	Contractor / PSC
Ambient Receiving Water	Full suite (Nutrients, Coliforms, Heavy Metals, DO)	Monthly	SW-02 (Dam Downstream)	Certified Lab / PSC

13.5.14.4 Resources Required

Treatment Infrastructure: STPs for temporary camps; permanent STP for the BHPL colony; API Oil-Water Separators; pH neutralization dosing units.

Monitoring Equipment: Portable multi-parameter water quality meters (pH, DO, turbidity, conductivity); laboratory sampling kits (BOD/COD bottles).

Spill Management: Hydrocarbon spill kits, absorbent booms, specialized hazardous waste containment drums.

Personnel: Dedicated STP/ETP plant operators; environmental field monitors (PSC); licensed hazardous waste and vacuum truck contractors.

13.5.14.5 Institutional Arrangements

EPC Contractor: Legally and financially responsible for procuring, installing, operating, and maintaining all STPs, API separators, and ZLD systems during construction. Must submit monthly effluent testing logs to the PSC.

PSC (Supervision Consultants): Responsible for conducting weekly unannounced effluent sampling, auditing the ZLD systems, and issuing immediate work-stoppage notices if raw sewage or industrial effluent is found discharging into the environment.

ESHS (Environmental Social Health and SafetyUnit): Oversees overall compliance, manages the permanent ETP/STP systems during the 100-year operational phase, and addresses any community grievances related to wastewater odors or pollution.

Department of Water (DoW) & NEC: Conduct regulatory oversight, review environmental monitoring reports, and enforce the Bhutan Environmental Standards (ES 2020).

13.5.15 Surface water quality management plan

The BHPP will fundamentally interact with and alter the local hydrological network, comprising the main Wangchhu River, critical tributaries (Jhililum Chhu, Motolum Chhu, Zanteylum Chhu), and highly sensitive community drinking water springs (Tsimasham, SW-05, SW-07, Nayakha Chhu SW-09, and Chanachen Spring SW-10).

The 2025 Physical Environmental Baseline established a dual reality: the chemical water quality is pristine (a "zero-tolerance" baseline with no heavy metals or hydrocarbons), but the bacteriological quality of community springs is highly vulnerable, showing dry-season faecal coliform contamination. Furthermore, the Wangchhu River demonstrates high sensitivity to suspended sediment loads. This Surface Water Quality Management Plan mandates strict engineering controls including Zero Liquid Discharge (ZLD) systems, continuous Environmental Flows (E-flows), and rigorous effluent treatment to protect these vital aquatic ecosystems and community water supplies.

13.5.15.1 Environmental Impacts and Sensitive Receptors

Without stringent water quality management, the project's construction and operational phases will trigger the following severe impacts across key receptors:

Chemical Contamination (The "Zero-Tolerance" Risk): The operation of RCC/CVC batching plants near Chanachen generates highly alkaline wastewater (cement wash). Unmanaged discharge, along with hydrocarbon spills from the main workshops, will instantly violate the pristine chemical baseline of the Wangchhu River, causing acute toxicity to aquatic life (*Schizothorax richardsonii*).

Sedimentation and Turbidity: Massive earthworks and muck disposal (MD-1, MD-2, MD-4) will cause severe sediment runoff. This increases turbidity, which smothers fish spawning grounds and degrades the water quality at downstream receptors (SW-02) and the 3.25 km critical reach leading to the Chhukha Dam.

Bacteriological Pollution: The discharge of untreated sewage from Labour Camps 1 & 2 will introduce massive nutrient and pathogen loads into the river and groundwater.

Altered Flow Regimes & Eutrophication: During operation, the 205 m dam will impound 329.16 million m^3 of water. Without adequate E-flows, the downstream riverbed will dry out. Concurrently, stagnant water in the reservoir can lead to thermal stratification, eutrophication (algal blooms), and a drop in dissolved oxygen (DO).

13.5.15.2 Mandatory Mitigation Measures (Phase-Wise)

Implementation of these measures is the strict legal responsibility of the EPC Contractor during construction and BHPL during operation, subject to enforcement by the PSC and regulatory authorities.

Pre-Construction Phase (Planning & Buffering)

Strict Buffer Zones: The Contractor must establish and physically demarcate a mandatory 50-meter "No-Go" Buffer Zone around all identified community drinking water springs (SW-05, SW-07, SW-09, SW-10). No machinery parking, fuel storage, or material stockpiling is permitted within these zones.

Drainage and Outfall Planning: All construction camp and workshop drainage systems must be engineered prior to mobilization, ensuring that no surface runoff discharges directly into the Wangchhu River without first passing through a settlement or treatment mechanism.

Construction Phase (Active Pollution Control)

Zero Liquid Discharge (ZLD) at Batching Plants: The RCC/CVC batching and crushing plants located near Chanachen must operate on a ZLD principle. All concrete wash-water must be routed through a pH neutralization unit (using acid dosing or CO_2) to achieve a pH of 6.5–8.5, followed by multi-stage sedimentation. The treated water must be recycled for aggregate washing or dust suppression. Direct discharge of concrete effluent into the river is strictly prohibited.

Workshop Hydrocarbon Control: All vehicle maintenance yards and fuel depots must be built on impermeable concrete pads surrounded by 110% volume containment bunds. Drainage from these areas must pass through standardized API Oil, -Water Separators before environmental discharge.

Sewage Treatment: The discharge of raw or partially treated sewage is prohibited. Permanent colonies and temporary labour camps must be equipped with adequately sized Sewage Treatment Plants (STPs) or engineered septic systems. Effluent must meet Bhutan Environmental Standards (ES 2020) before discharge.

In-Stream Sediment Management: During the construction of the coffer dams and diversion tunnels, turbidity curtains and temporary sediment traps must be utilized to minimize downstream silt plumes.

Operation Phase (Flow and Reservoir Management by BHPL

Mandatory Environmental Flow (E-Flow): To sustain the downstream aquatic ecosystem and dilute potential pollutants, BHPL must ensure the continuous release of an E-Flow..

Controlled Sediment Flushing: Reservoir sediment flushing using the mid-level outlets (EL 1915 m) must be strictly scheduled during the peak monsoon season (June–September) when natural river volumes provide massive dilution capacity. BHPL must provide 2-week advance notification to downstream communities (Tsimasham) prior to flushing.

Ecological Vector Control: To mitigate mosquito breeding in the reservoir's shallow margins, ESHS will rely on water-level fluctuation management and the promotion of native predatory fish and macroinvertebrates. The introduction of alien invasive species (e.g., Gambusia mosquito fish) is strictly prohibited.

Water Quality Maintenance: Maintain vegetative buffer zones along the 17.25 km reservoir perimeter to naturally filter agricultural runoff and prevent nutrient loading (nitrates/phosphates) that causes algal blooms.

Decommissioning Phase

Safe Dismantling of In-Stream Structures: The removal of coffer dams (EL 1890 m and EL 1857 m) must be scheduled during the lowest flow period (winter). Controlled dismantling techniques must be used to prevent a sudden, massive release of trapped sediment.

Wastewater Infrastructure Removal: All temporary STPs, API separators, and chemical storage areas must be safely pumped out, neutralized, and decommissioned by licensed hazardous waste handlers to prevent terminal contamination of the site.

13.5.15.3 Monitoring and Compliance Program

Table 92: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
Real-Time River Monitoring	Turbidity, DO, pH, Temperature	Continuous (Automated)	SW-02 (Dam Downstream)	Contractor / PSC
Drinking Water Safety	Faecal Coliforms (must be 0), Turbidity, pH	Weekly	SW-05, SW-09, SW-10	Contractor / PSC
Industrial Effluent Checks	pH, Oil & Grease (mg/L), TSS	Weekly	Batching Plant & Workshop Outfalls	PSC
Ambient Surface Water Sampling	Full suite (BOD, COD, Heavy Metals, Nutrients)	Seasonally (4 times/year)	SW-01, SW-02, SW-09	Certified External Lab / PSC
E-Flow Compliance	Discharge volume (m^3/s)	Continuous (Automated)	Tailrace / E-flow outlet	ESHS
Sediment Transport	TSS (mg/L), Sediment Load	Weekly (Monsoon/Flushing)	SW-01 (Upstream), SW-02	PSC / BHPL

13.5.15.4 Resources Required

Treatment Infrastructure:r STPs for camps; API Oil-Water Separators for workshops; automated pH neutralization dosing plants for batching units.

Monitoring Equipment: Automated, real-time water quality monitoring buoys/sensors (pH, DO, Turbidity) installed at SW-02; portable multi-parameter water testing kits for daily field checks.

Spill Response: Rapid-response chemical and hydrocarbon spill kits (absorbent booms, pads, specialized disposal bags) stationed at all workshops and active river-edge work fronts.

Laboratory Services: Retained contract with an accredited laboratory (e.g., in Bhutan or Kolkata) for complex seasonal bacteriological and heavy-metal analysis. Monitor BOD, COD, DO, nitrates and faecal coliform.

13.5.15.5 Institutional Arrangements

EPC Contractor: Legally and financially responsible for procuring, installing, and maintaining all STPs, ZLD systems, and API separators. Must conduct weekly compliance sampling and submit the C-ESMP.

PSC (Supervision Consultants): Reviews automated sensor data, conducts unannounced effluent sampling, and possesses the authority to halt batching/workshop operations if ZLD or oil-separation systems fail.

ESHS (Environment Social Health and Safety Unit): Manages the permanent E-flow releases, coordinates downstream notifications for sediment flushing, and assumes long-term water quality monitoring during the 100-year operational life.

Department of Water (DoW) & NEC: Provide regulatory oversight, enforce the Bhutan Water Act 2014 and Bhutan Environmental Standards (ES 2020), and verify E-flow compliance.

13.5.16 Sanitation and solid waste management plan

The construction of the BHPP will generate massive and diverse waste streams. During peak construction, the site will host approximately 970 contractor personnel and 181 BHPL staff, primarily concentrated at Labour Camp-1 (7.41 acres) and Labour Camp-2 (1.24 acres). In addition to the domestic waste and sewage generated by this influx, the project will produce massive volumes of construction debris (from 5.65 million m^3 of excavation), hazardous wastes (lubricants, paints), and biomedical waste from site clinics.

The 2025 baseline surveys established that the Wangchhu River and surrounding soils currently exhibit a pristine, "zero-tolerance" chemical baseline. If unmanaged, project waste will rapidly contaminate these pristine soil and water resources, trigger outbreaks of waterborne diseases, and degrade the aesthetic value of the region. This Sanitation and Solid Waste Management Plan establishes the mandatory protocols for the segregation, collection, treatment, and disposal of all waste streams throughout the project lifecycle.

13.5.16.1 Environmental and Health Risks

Without stringent waste management, the project presents the following severe risks:

Water Quality & Aquatic Ecosystems: Untreated sewage or leachates from solid waste dumps discharging into the Wangchhu River will cause severe nutrient loading, eutrophication, and an immediate drop in dissolved oxygen, threatening native aquatic species (*Schizothorax richardsonii*).

Public Health & Disease: Baseline surveys confirmed the presence of faecal coliforms in community drinking springs (SW-05, SW-07, SW-10). Indiscriminate open defecation or sewage leakage will exacerbate this contamination, leading to outbreaks of cholera and dysentery. Furthermore, stagnant water in poorly drained waste dumps will breed vectors for dengue and malaria.

Soil Contamination: The improper disposal of hazardous construction waste (used oils, chemical admixtures, heavy metals) will permanently sterilize the highly fertile topsoils and leach into the groundwater table.

Aesthetic & Odor Impacts: Open burning of plastics and the accumulation of unmanaged municipal solid waste (MSW) will generate toxic smoke, foul odours, and severe visual scarring for nearby communities (Chanachen, Bunakha) and heritage sites.

13.5.16.2 Mandatory Mitigation Measures (Phase-Wise)

Implementation of these measures is the strict responsibility of the EPC Contractor, subject to enforcement by the PSC and BHPL.

Pre-Construction Phase (Planning & Procurement)

Waste Infrastructure Siting: The Contractor must design camp layouts incorporating adequately sized, engineered Sewage Treatment Plants (STPs) or multi-chambered septic/soak-pit systems. These must be sited at least 50 meters away from any surface water body.

Vendor Contracts: Prior to mobilization, the Contractor must execute formal agreements with authorized/licensed waste management agencies for the off-site transport and recycling of hazardous wastes (e.g., used engine oil, batteries) and scrap metal.

Procurement: Procurement of color-coded waste segregation bins, bio-toilets (for active work fronts), and composters must be completed before the main workforce arrives.

Construction Phase (Active Waste Management)

Domestic Wastewater & Sanitation:

- Provide a minimum of 1 toilet per 15 workers in all camps, strictly segregated by gender, with lighting and running water.
- Raw sewage discharge into the Wangchhu River is strictly prohibited. All camp wastewater must pass through an STP or engineered septic system. Treated effluent must meet Bhutanese discharge standards and be reused for site dust suppression where possible.
- Solid Waste Segregation at Source:
- The Contractor must enforce a strict color-coded bin system across all camps and work sites: Green (Biodegradable/Organic), Blue (Recyclable Plastics/ Paper), Red (Hazardous/Chemicals), Yellow (Biomedical), and Black (Inert/Construction).
- Organic kitchen waste from the centralized messes must be composted on-site in enclosed aerated pits to prevent attracting rodents and wildlife.

Hazardous Waste Protocol:

- Used lubricants, hydraulic fluids, paints, and concrete admixtures must be stored in specialized sealed drums within a roofed, concrete-lined storage shed surrounded by a 110% volume containment bund. Disposal is strictly restricted to licensed hazardous waste handlers.

Biomedical Waste:

- Waste from the camp clinics (syringes, bandages) must be stored in puncture-proof yellow containers and safely transported to the Chhukha Hospital incinerator under a formal MoU, or incinerated on-site using an approved medical-grade incinerator.

Zero Open-Burning Policy: The open burning of any waste (especially plastics, tires, and rubber) is universally prohibited across the project footprint.

Operation Phase (Long-Term Management by BHPL)

Reservoir Driftwood & Debris Clearing: BHPL must implement a routine clearing program to remove driftwood, plastics, and floating solid waste that will naturally accumulate at the dam structure across the 17.25 km reservoir to prevent turbine blockages and localized eutrophication.

Permanent Facilities: Maintain and operate the permanent STPs servicing the administrative offices and the operational staff colony.

Ongoing Segregation: Continue the color-coded MSW segregation system for the 84 operational staff, ensuring recyclables are sold to authorized vendors and organic waste is composted.

Decommissioning Phase

Safe Dismantling of STPs: Septic tanks and temporary STPs must be safely pumped out (desludged) by vacuum trucks and treated at municipal facilities before being dismantled or safely backfilled.

Demolition Debris: Segregate construction and demolition (C&D) debris. Inert materials (concrete rubble, brick) should be crushed and reused for local road base material or safely buried in designated, approved depressions covered with topsoil.

Hazardous Remediation: Conduct a soil contamination audit at the main workshop and batching plant sites. Any hydrocarbon-contaminated soil must be excavated and treated before the land is handed back to the government or community.

13.5.16.3 Monitoring and Compliance Program

Table 93: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	Detailed Waste Management Plan approved	Pre-construction	Project Office	Contractor / PSC
Wastewater Effluent Quality	BOD, COD, TSS, pH, Faecal Coliforms (STP outlet)	Monthly	Camp STPs / Septic outflows	Contractor / PSC

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
Sanitation Inspections	Toilet functionality, cleanliness, no open defecation	Weekly	Camps & active work fronts	PSC
Waste Segregation Audits	Correct use of color-coded bins; no mixed dumping	Weekly	Camps, kitchens, workshops	PSC
Hazardous Waste Logs	Inventory logs of used oils stored vs. handed to licensed vendors	Monthly	Main Workshop / Stores	Contractor / PSC
Biomedical Waste Tracking	Manifests of medical waste transferred to hospital/incinerated	Monthly	Camp Clinics	Contractor / PSC
Water Quality Monitoring	Detection of leachates (coliform, TSS) downstream	Weekly	SW-2 (Dam Downstream)	PSC

13.5.16.4 Resources Required

Sanitation Infrastructure: r STPs or materials for engineered septic tanks; bio-toilets for remote tunnel portals; handwashing stations.

Waste Containment: Hundreds of heavy-duty color-coded bins; puncture-proof sharps containers; sealed chemical storage drums.

Processing Equipment: Enclosed organic composters; balers/shredders to reduce the volume of recyclable plastics/cardboard; dedicated covered waste-transport trucks.

Safety & PPE: Heavy-duty puncture-resistant gloves, N95 masks, aprons, and steel-toed boots for all dedicated sanitation and waste-handling staff.

Personnel: Dedicated Camp Boss/Hygiene Manager, trained waste sorting staff, and licensed hazardous material handlers.

13.5.16.5 Institutional Arrangements

EPC Contractor: Legally and financially responsible for executing the Waste Management Plan, procuring all bins and STPs, paying authorized disposal vendors, and ensuring daily camp hygiene.

PSC (Supervision Consultants): Responsible for conducting weekly waste and sanitation audits, testing STP effluent, and issuing non-compliance notices (and associated financial penalties) for open dumping or burning.

ESHS (Environmental Social Health and Safety Unit): Provides overall project oversight, resolves community grievances regarding waste odours or litter, and takes over solid waste management for permanent facilities during the Operation Phase.

Regulatory Agencies (NEC, Ministry of Health): Review compliance reports, conduct unannounced site inspections, and enforce the Waste Prevention and Management Act 2009.

13.5.17 Public health delivery plan/human health management plan

Hydropower projects bring together massive workforces and local communities, often in remote areas with limited existing health infrastructure. During peak construction, the BHPP will host approximately 970 contractor personnel and 181 BHPL staff. These workers will be densely accommodated at Labour Camp-1 (7.41 acres near Bunakha village) and Labour Camp-2 (1.24 acres below Chanachen village).

The rapid influx of over 1,000 individuals into rural communities (Chanachen, Bunakha, Nayakha) creates acute risks regarding communicable diseases, occupational injuries, pressure on local water resources, and community friction. This Public Health Delivery Plan establishes the mandatory occupational health, safety, and community well-being standards required to safeguard human health throughout the project lifecycle. Crucially, the project's Occupational Health and Safety (OHS) management framework is mandated to strictly comply with the Royal Government of Bhutan's (RGoB) laws and regulations, the ADB Safeguard Policy Statement (SPS 2009), and the World Bank Group/IFC General Environmental, Health, and Safety (EHS) Guidelines.

13.5.17.1 Human Health and Safety Risks

Without stringent management, the project's scale and the specific baseline conditions present the following severe health risks:

- Community Health & Waterborne Diseases: Baseline water quality surveys (2025) confirmed the presence of faecal coliforms in community drinking water springs (SW-05, SW-07, SW-10) during the dry season. The influx of workers threatens to further contaminate and deplete these vulnerable sources, triggering outbreaks of cholera, dysentery, or typhoid.
- Air & Noise-Induced Stress: Baseline data shows Chanachen enjoys a pristine acoustic environment (36-40 dBA), while the AH48 corridor already suffers from year-round NO_2 exceedances. Project-induced dust, blasting noise, and heavy equipment emissions will cause severe respiratory issues and sleep disturbance if unmitigated.
- Vector-Borne & Communicable Diseases: High-density worker camps are breeding grounds for communicable diseases (tuberculosis, influenza, COVID-19) and Sexually Transmitted Infections (STIs/HIV). Furthermore, stagnant water in borrow pits and the newly formed reservoir margins increase the risk of vector-borne diseases (malaria, dengue).
- Occupational Health & Safety (OHS): Heavy construction involving steep terrain, deep excavations, tunnelling, explosive blasting at INRQ-3, and heavy machinery (crushers, batching plants) poses constant risks of fatal accidents, musculoskeletal disorders, and hazardous chemical exposure.

13.5.17.2 Mandatory Mitigation Measures (Phase-Wise)

To ensure clear contractual accountability, mitigation measures are divided by project phase. Implementation is the strict responsibility of the EPC Contractor, overseen by the PSC and ESHS.

13.5.17.2.1 Pre-Construction Phase (Planning & Infrastructure Setup)

- Health Infrastructure & MoUs: Before mobilizing the main workforce, the Contractor must establish a fully equipped onsite first-aid clinic. The Contractor must also execute formal

Memorandums of Understanding (MoUs) with Chhukha Hospital and Thimphu Referral Hospital to guarantee emergency referral and trauma care capacity.

- Baseline Health Screening: All incoming workers must undergo a mandatory baseline medical screening (including checks for communicable diseases) prior to site induction.
- Engineered Camp WASH Facilities: Because raw surface water is bacteriologically unsafe, the Contractor must procure and install scalable, modular Water Treatment Plants (WTPs) featuring physical filtration and UV/chlorination to provide safe drinking water to all camps. Camps must be designed with engineered Sewage Treatment Plants (STPs) or adequately sized septic/soak-pit systems.

13.5.17.2.2 Construction Phase (Active Health Management)

- On-Site Medical Services: The Contractor must operate a central camp clinic staffed by at least one certified doctor and qualified nurses. A fully equipped, dedicated 24/7 Life Support Ambulance must be stationed permanently at the dam/powerhouse site for immediate emergency evacuation.
- Sanitation & Hygiene: Camps must provide a minimum of 1 toilet per 15 workers, segregated by gender, with proper lighting and handwashing stations. Open defecation is strictly prohibited. Independent food hygiene inspections must be conducted weekly in all centralized mess kitchens.
- Occupational Health and Safety (OHS): The Contractor must develop and implement a comprehensive OHS Management Plan that strictly complies with RGoB occupational health and safety regulations, ADB SPS (2009), and the IFC General EHS Guidelines. The Contractor must conduct a Hazard Identification and Risk Assessment (HIRA) for all active zones. The use of Personal Protective Equipment (PPE) including hard hats, high-visibility vests, steel-toed boots, N95 masks (for crusher/tunnel dust), and ear protection is mandatory. Zero-tolerance policies for alcohol or drug use on site must be strictly enforced.
- Disease & Vector Control: Implement mandatory vaccination programs (tetanus, typhoid, hepatitis) for workers. Conduct weekly vector-control spraying and active drainage of stagnant water in camps, borrow pits, and scrap yards, especially during the monsoon.
- Community Protection & Code of Conduct: Enforce a strict Worker Code of Conduct. The Contractor must conduct regular awareness programs on STIs, HIV/AIDS, and the prevention of Gender-Based Violence (GBV) and Sexual Exploitation, Abuse, and Harassment (SEAH) to protect local women in Chanachen, Bunakha, and Nayakha.

13.5.17.2.3 Operation Phase (Long-Term Management by BHPL)

- Permanent Health Infrastructure: ESHSmust maintain a permanent, staffed health clinic at the operational staff colony (accommodating 84 operational staff) to serve project personnel and provide emergency first-aid to nearby villagers.
- Reservoir Vector Management: Implement an ongoing vector management plan along the 17.25 km reservoir shoreline, monitoring for stagnant pools and mosquito breeding, particularly during reservoir drawdown periods.
- Community Health Outreach: ESHS should organize bi-annual health camps for the communities of Chanachen, Bunakha, and Nayakha, offering free medical check-ups and collaborating with the Ministry of Health on local vaccination drives.

- Operational OHS: Enforce strict electrical safety protocols, Arc Flash protection, and confined-space entry permits for all powerhouse and switchyard maintenance staff in alignment with RGoB and IFC EHS standards.

13.5.17.3 Decommissioning Phase

- Demolition OHS: Enforce strict PPE compliance during the dismantling of temporary coffer dams, batching plants, and camps. Specialized training must be provided for handling hazardous decommissioning materials (e.g., asbestos, residual oils, chemicals).
- Site Remediation: Ensure all temporary septic tanks, soak pits, and waste dumps are safely emptied, treated, and backfilled to prevent residual public health hazards and groundwater contamination.

Table 94: Monitoring and Compliance Program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	OHS Plan, Camp Layouts, Emergency Response Plan approved	Pre-construction	Project Office	Contractor / PSC
Drinking Water Quality	Faecal coliforms (must be 0), Free Chlorine Residual, Turbidity	Monthly	Labour Camps 1 & 2	Contractor / PSC
Clinic / Ambulance Readiness	Staff attendance, medicine stock, ambulance functionality	Weekly	Camp Clinics / Dam Site	PSC
OHS Compliance	Accident rates (LTIFR), near-miss reports, PPE compliance %	Weekly	All active work sites	Contractor / PSC
Sanitation Inspections	Toilet functionality, camp cleanliness, kitchen hygiene	Weekly	Labour Camps 1 & 2	PSC
Vector Control	Identification of stagnant water; spraying log records	Bi-weekly (Monsoon)	Camps, active quarries	Contractor / PSC
Community Grievances	Number of health/social complaints from local villages	Monthly	Chanachen, Bunakha	ESHS/ PSC
Disease Surveillance	Incidence rates of STIs, respiratory, and waterborne diseases	Monthly	Camp Clinics	Contractor / MoH

Table 95: Resources Required

Category	Specific Resources
Health Infrastructure	Fully equipped onsite clinic; 24/7 dedicated Life Support Ambulance; trauma kits, oxygen cylinders, stretchers, diagnostic equipment.
WASH & Sanitation	Modular Water Treatment Plants (WTPs); STPs or engineered septic systems; chlorination dosing pumps; water quality testing kits.
PPE & Safety	Hard hats, N95 respirators, safety goggles, ear-muffs/plugs, steel-toed boots, chemical handling gloves, full-body fall-arrest harnesses.

Category	Specific Resources
Medical Supplies	Vaccines (Tetanus, Typhoid, Hepatitis); broad-spectrum antibiotics, antimalarials, burn kits, snake-bite anti-venom, emergency trauma supplies.
Personnel	Certified Site Doctor, qualified nurses/paramedics, dedicated EHS Manager, trained OHS supervisors, Community Liaison Officer.

Table 96: Institutional Arrangements

Stakeholder	Responsibilities
EPC Contractor	Legally responsible for funding and implementing all OHS, camp WASH facilities, medical staffing, and reporting. Must submit the C-ESMP and an OHS Management Plan strictly compliant with RGoB, ADB SPS, and IFC EHS standards.
PSC (Supervision Consultants)	Reviews and approves the Contractor's EHS plans; conducts weekly site safety walks; audits clinic readiness and water quality; enforces work-stoppages for severe safety breaches.
ESHS	Overall project oversight; manages the Grievance Redress Mechanism (GRM); coordinates community outreach; takes over health delivery during the Operation Phase.
Ministry of Health (MoH)	Provides technical guidance; integrates project disease surveillance data into national databases; supports regional outbreak response.

13.5.18 Energy conservation measures plan

The construction of the BHPP encompassing a 205 m high RCC dam, a 180 MW surface powerhouse, extensive aggregate crushing, and the accommodation of over 1,150 project personnel (contractors and staff) is a highly energy-intensive undertaking. While the ultimate project output is renewable energy, the 60 months construction phase will consume significant electricity (via the regional grid) and fossil fuels (diesel for heavy machinery, transport fleets, and backup generators).

To minimize the Project's carbon footprint, control operational costs, and align with Bhutan's sustainable development goals and ADB's Resource Conservation requirements, a rigorous Energy Conservation and Management Plan must be implemented across both the temporary construction operations and the permanent electro-mechanical design.

13.5.18.1 Environmental and Economic Risks

Failure to implement strict energy conservation measures will result in the following adverse impacts:

Airshed Degradation: Running inefficient, oversized diesel generators on low loads, and allowing heavy machinery to idle unnecessarily, drastically increases the emission of Nitrogen Oxides (NOx), Particulate Matter ($PM_{2.5}$), and greenhouse gases. This will directly exacerbate the already stressed air quality baseline along the AH48 corridor.

Grid Overload: Inefficient use of construction power (e.g., using incandescent lighting or uninsulated winter heating) places unnecessary strain on the local electrical grid, potentially causing localized brownouts for nearby communities (Chanachen, Bunakha).

Economic Inefficiency: Wasted diesel and electricity exponentially drive up the EPC Contractor's operational expenditures, reducing overall project economic efficiency.

13.5.18.2 Mandatory Mitigation Measures (Phase-Wise)

Construction Phase (EPC Contractor Obligations)

The EPC Contractor is legally bound to integrate energy optimization into daily site operations. These measures must be detailed in the Contractor's Construction Environmental and Social Management Plan (C-ESMP):

Machinery and Fleet Optimization: Implement a strict "anti-idling" policy (maximum 5 minutes) for all heavy earthmoving equipment and transport trucks. Machinery must be regularly serviced and tuned to maintain optimal fuel efficiency.

Generator Load Management: Where off-grid diesel generators are necessary, they must be correctly sized to the required electrical load. Running oversized generators on low loads is strictly prohibited due to severe fuel inefficiency and high emissions. Where feasible, generators should be synchronized or hybridized with temporary solar arrays.

Efficient Lighting Systems: 100% of indoor lighting in temporary site offices, laboratories, and worker camps (Labour Camps 1 & 2) must utilize LED technology. High-mast lighting for active night-time work areas (e.g., batching plants, dam toe) must use energy-efficient LED floodlights rather than traditional metal halides. Standalone solar-powered streetlights must be installed along camp perimeters and access roads.

Camp and Office Insulation: Prefabricated site offices and worker dormitories must incorporate adequate thermal insulation. This significantly reduces the electrical base-load required for winter space heating and summer cooling.

Smart HVAC and Appliances: All air conditioning units, room heaters, and kitchen appliances procured for site offices and centralized mess halls must carry high-efficiency "star ratings" (or international equivalents).

Operational Phase & Permanent Design Measures (BHPL)

Energy conservation must be embedded into the final electro-mechanical design and the permanent operational infrastructure:

Powerhouse Efficiency: Ensure the procurement and installation of high-efficiency vertical Francis turbines, generators, and low-loss transformers to maximize the 180 MW output with minimal mechanical/electrical losses.

Auxiliary Systems Optimization: Mandate the use of Variable Frequency Drives (VFDs) and Brushless Direct Current (BLDC) motors for all powerhouse auxiliary systems (cooling water pumps, ventilation fans, HVAC). This ensures they only consume power strictly proportional to real-time demand.

Green Building Design: Permanent project administration buildings and operational staff colonies must incorporate passive solar design, maximizing natural daylighting, and utilizing rooftop Solar PV panels to offset the building's auxiliary power consumption.

13.5.18.3 Monitoring and Compliance Program

While specific national legal thresholds for construction-phase energy use do not currently exist, the Project will enforce these measures contractually to ensure best practices.

Table 97: Monitoring program

Monitoring Activity	Parameters / Indicators	Frequency	Location	Responsibility
C-ESMP Approval	"Energy Conservation Method Statement" approved	Pre-mobilization	Project Office	Contractor / PSC
Sub-Metering & Power Audits	Grid electricity consumed (kWh) mapped against civil works completed (establishing energy intensity)	Monthly	Sub-meters at Crushers, Camps, Tunnel Portals	Contractor / PSC
Fuel & Generator Efficiency	Diesel consumed (Liters); generator logbooks for load-factor efficiency	Monthly	Main Stores, Active Gen-Sets	Contractor / PSC
Visual Lighting Audits	100% LED compliance; verification of no "daylight burning" of outdoor floodlights	Weekly	All Camps and Active Work Fronts	PSC
Anti-Idling Enforcement	Spot checks on idling machinery >5 minutes	Daily	Haul roads, Quarries, MD sites	PSC / Site Supervisors
Worker Sensitization	Energy conservation included in Tool-Box Talks (e.g., turning off heaters)	Weekly	All active sites	Contractor

13.5.18.4 Resource Required

Hardware: Smart electrical sub-meters; LED industrial floodlights and indoor bulbs; standalone solar streetlights; high-star-rated HVAC units; VFDs/BLDCs for pumping systems; and high-grade thermal insulation materials for temporary camps.

Software/Management: Energy tracking software or customized spreadsheet dashboards to generate monthly energy-intensity reports for the PSC.

Personnel: A designated Electrical/Mechanical Engineer within the PSC team tasked specifically with auditing energy and fuel efficiency during the construction phase.

13.5.18.5 Institutional Arrangements

EPC Contractor: Legally and financially responsible for procuring energy-efficient equipment (LEDs, insulated prefabs), installing sub-meters, enforcing anti-idling rules, and submitting monthly Energy and Fuel Consumption Reports.

PSC (Supervision Consultants): Responsible for reviewing the monthly energy data, conducting quarterly field energy audits, and identifying areas where the Contractor is wasting electricity or fuel.

BHPL (Electro-Mechanical Unit): Ensures that VFDs, high-efficiency turbines, and green building designs are strictly integrated into the permanent project BoQ and operational protocols.

13.5.19 Environmental, Social, Health and Safety Management Plan

The BHPP is a storage hydropower development project proposed on the Wangchhu River in Bhutan under the responsibility of BHPL. The project involves construction activities including dam and intake works, diversion structures, tunnel excavation, powerhouse construction, access roads, transmission line components, camps, and ancillary facilities.

Construction activities associated with hydropower projects present significant occupational health and safety (OHS) risks due to excavation works, underground tunneling, slope instability, blasting, operation of heavy machinery, work at height, confined space activities, river diversion works, electromechanical installation, traffic movement, and interaction with hazardous materials.

This Occupational Health and Safety (OHS) Plan has been prepared to establish a systematic framework for the identification, management, monitoring, and mitigation of occupational health and safety risks during the construction of BHPP.

13.5.19.1 Objectives of the OHS Plan

The objectives of this OHS Plan are to:

- Protect workers from occupational injuries, illnesses, and accidents;
- Establish procedures and controls for safe construction activities;
- Ensure compliance with applicable Bhutanese laws, regulations, and international standards;
- Promote a positive safety culture among all project personnel;
- Minimize occupational risks associated with hydropower construction activities;
- Define roles and responsibilities for OHS implementation;
- Establish emergency preparedness and response procedures;
- Ensure continuous monitoring, reporting, and improvement of OHS performance.

13.5.19.2 Applicable Policies, Laws and Standards

The OHS Plan shall comply with the following:

National Requirements (Bhutan)

- Labour and Employment Act of Bhutan;
- Occupational Health and Safety requirements under applicable Bhutanese legislation;
- Water Act of Bhutan, 2011;
- Environmental Assessment Act and related regulations;
- Road Safety and Construction Safety requirements;
- Applicable directives from the Department of Labour and relevant agencies.

International Standards and Guidelines

- Asian Development Bank (ADB) Safeguard Policy Statement (2009);
- IFC General Environmental, Health and Safety (EHS) Guidelines;

- IFC EHS Guidelines for Electric Power Transmission and Distribution;
- IFC EHS Guidelines for Construction Materials Extraction;
- World Bank Group General EHS Guidelines;
- Good International Industry Practice (GIIP).

13.5.19.3 Scope of the OHS Plan

This OHS Plan applies to:

All project construction activities;

- Contractors and subcontractors;
- Consultants and supervision personnel;
- Visitors entering project sites;

All temporary facilities, including camps, workshops, batching plants, crushers, stockpiles, muck disposal sites, and laydown areas.

The plan covers:

- Physical hazards;
- Chemical hazards;
- Biological hazards;
- Ergonomic hazards;
- Psychosocial risks;
- Emergency response;
- Occupational health management;
- Incident reporting and investigation;
- Monitoring and auditing.

13.5.19.4 OHS Policy Statement

BHPL and Contractors shall commit to:

- Providing safe and healthy working conditions;
- Preventing workplace injuries and occupational illnesses;
- Implementing hazard identification and risk assessment procedures;
- Providing adequate training and supervision;
- Ensuring workers' participation in OHS matters;
- Providing appropriate personal protective equipment (PPE);
- Investigating all incidents and implementing corrective actions;
- Maintaining compliance with legal and contractual requirements;
- Promoting continual improvement in OHS performance.

13.5.19.5 Organizational Structure and Responsibilities

Bunakha Hydropower Project Limited

BHPL shall:

- Provide overall oversight for implementation of the OHS Plan

- Ensure contractors comply with contractual OHS requirements
- Review OHS performance reports
- Conduct periodic inspections and audits
- Ensure adequate resources are allocated for OHS management.

Contractor

The Contractor shall prepare, submit for approval, implement, monitor, and periodically update a comprehensive Contractor's Environmental, Social, Health and Safety Management Plan (CESHSMP) prior to commencement of construction activities. The CESHSMP shall be fully consistent with this ESIA, Environmental and Social Management Plan (ESMP), Occupational Health and Safety (OHS) Plan, Labour Management Plan, Biodiversity Action Plan, Emergency Response Plan, and other relevant management plans.

Contractor shall appoint a dedicated Occupational Health and Safety (OHS) Officer responsible for preparing, implementing, and overseeing all OHS-related plans and activities.

The CESHSMP shall include, at minimum:

- Project-specific Occupational Health and Safety Management System
- Job Hazard Analysis (JHA) and Task Risk Assessment (TRA)
- Safe Work Method Statements (SWMS)
- Blasting Management Plan
- Explosives Storage and Handling Procedures
- Emergency Response Plan (ERP)
- Traffic Management Plan
- Community Health and Safety Management Plan
- Contractor Environmental Management Plan
- Slope Stability and Geotechnical Risk Management Plan
- Tunnel Safety Management Plan
- Confined Space Management Plan
- Permit-to-Work Procedures
- Incident Investigation Procedures
- Monitoring and Reporting Framework

All plans shall comply with Bhutanese legislation, ADB SPS (2009), IFC General EHS Guidelines, World Bank Group EHS Guidelines, applicable international standards, and Good International Industry Practice (GIIP).

Occupational Health and Safety Management System

The Contractor shall establish, implement, maintain, and continually improve an Occupational Health and Safety Management System (OHSMS) consistent with internationally recognized management system principles, such as ISO 45001 or an equivalent standard, throughout the construction period.

The OHSMS shall include, at minimum:

- Occupational Health and Safety Policy
- legal and contractual compliance register

- hazard identification and risk assessment (HIRA)
- competency, training, and awareness programmes
- permit-to-work system
- contractor and subcontractor management
- emergency preparedness and response
- incident reporting, investigation, and corrective action procedures
- inspection, monitoring, and performance measurement
- internal audits and management reviews
- continual improvement mechanisms

The Contractor shall periodically review the effectiveness of the OHSMS and revise it as construction activities, project risks, or legal requirements change.

OHS Manager / Safety Officer (DGPC)

The OHS Manager shall:

- Coordinate implementation of OHS requirements
- Conduct inspections and audits
- Maintain OHS records
- Facilitate training and awareness programs
- Investigate incidents and recommend corrective actions
- Ensure emergency preparedness measures are functional.

Supervisors

Supervisors shall:

- Ensure workers follow safe work procedures
- Conduct daily pre-task briefings
- Stop unsafe work practices
- Verify PPE use
- Report hazards and incidents.

Workers

Workers shall:

- Follow safety instructions and procedures;
- Properly use PPE;
- Report unsafe conditions;
- Participate in trainings and toolbox talks;
- Avoid unsafe acts and behaviours.

13.5.19.6 Hazard Identification and Risk Assessment

Hazard Identification and Risk Assessment (HIRA) shall be conducted prior to the commencement of activities.

The assessment shall consider:

- Nature of work activity;
- Severity of potential consequences;
- Frequency and duration of exposure;
- Number of exposed persons;
- Existing controls;
- Residual risks.

Risk control measures shall follow the hierarchy of controls, giving priority to elimination, substitution, engineering controls, administrative controls, and finally personal protective equipment (PPE). PPE shall be considered the last line of defense and shall not replace higher-order risk control measures where these are reasonably practicable.

13.5.19.7 Risk Rating Categories

Table 98: Risk categories

Risk Level	Description	Required Action
Low	Minor injury or low probability	Routine controls
Medium	Moderate injury potential	Additional mitigation required
High	Serious injury or major accident potential	Immediate corrective measures
Very High	Fatality or multiple serious injuries	Work is prohibited until controls are implemented

13.5.19.8 Key Construction OHS Risks

Major construction risks associated with Bunakha HPP include:

- Excavation collapse and trench failure
- Blasting and explosive handling
- Tunnel construction hazards
- Rockfall and slope instability
- Working at height
- Heavy equipment operation
- Electrical hazards
- Traffic and vehicle accidents
- Confined space entry
- Drowning and river-related risks
- Dust and air quality impacts
- Noise and vibration exposure
- Fire and explosion hazards
- Manual handling injuries
- Fatigue and heat/cold stress
- Hazardous material exposure.

BHPP Site-Specific OHS Risk Context

Construction activities at Bunakha HPP will be undertaken in steep Himalayan terrain with high rainfall, fragile geology, and difficult access conditions. Key occupational risks include

landslides, rockfalls, flash floods, tunnel hazards, slope instability, confined-space risks, and emergency access limitations, particularly during monsoon periods.

The Contractor shall integrate weather monitoring, slope inspections, emergency preparedness, and geotechnical safety measures into construction planning. High-risk activities shall be suspended during severe weather events, unstable slope conditions, or emergencies.

13.5.19.9 OHS mitigation measures

General Site Safety

- Site-specific safety plans shall be prepared before commencement of work.
- Hazardous areas shall be barricaded and signposted.
- Access to work areas shall be controlled.
- Daily toolbox talks shall be conducted.
- Safety signage shall be installed in English and Dzongkha where appropriate.
- Good housekeeping shall be maintained at all times.
- Adequate lighting shall be provided for night works.

Personal Protective Equipment (PPE)

Mandatory PPE shall include:

- Safety helmet;
- High-visibility vest;
- Safety shoes;
- Gloves;
- Eye protection;
- Hearing protection where required.
- Additional PPE shall be provided based on specific tasks including:
- Respiratory protection;
- Fall arrest harnesses;
- Welding shields;
- Chemical-resistant gloves and aprons;
- Life jackets for river works.
- PPE shall comply with recognized standards and shall be regularly inspected and replaced when damaged.

Excavation and Trenching Safety

- Excavations shall be inspected daily.
- Benching and sloping shall be implemented wherever feasible.
- Shoring or trench support systems shall be used where sloping is not feasible.
- Safe access and egress shall be provided.
- Excavated materials shall be stored away from trench edges.
- Barricades and warning signs shall be installed.
- Water accumulation shall be controlled through dewatering systems.

Tunnelling and Underground Works

- Tunnel ventilation systems shall be installed and maintained.

- Gas monitoring shall be conducted regularly.
- Emergency escape routes shall be established.
- Ground support systems shall be installed based on geotechnical conditions.
- Underground communication systems shall be maintained.
- Entry into underground works shall be controlled.

Blasting Safety

- Blasting shall only be conducted by licensed personnel.
- Blasting schedules shall be communicated to nearby communities and workers.
- Exclusion zones shall be established.
- Explosives shall be stored in approved magazines.
- Misfire procedures shall be established.
- Blasting records shall be maintained.

Working at Height

- Work at height permits shall be implemented.
- Full body harnesses shall be used.
- Scaffolds shall be inspected by competent persons.
- Guardrails and fall protection systems shall be installed.
- Ladders shall be properly secured and maintained.

Electrical Safety

- Lockout/tagout procedures shall be implemented.
- Temporary electrical systems shall be properly grounded.
- Electrical panels shall remain secured.
- Damaged cables and tools shall not be used.
- Only authorized personnel shall conduct electrical works.

Machinery and Equipment Safety

- Operators shall be trained and licensed.
- Equipment inspection checklists shall be maintained.
- Reversing alarms and warning systems shall be functional.
- Preventive maintenance shall be conducted.
- Unsafe machinery shall be removed from service.

Traffic and Road Safety

- Traffic Management Plans shall be implemented.
- Speed limits shall be enforced.
- Spotters/flag persons shall be deployed where necessary.
- Vehicle inspections shall be conducted regularly.
- Defensive driving training shall be provided.

River and Water Safety

- Life jackets shall be mandatory near water bodies.
- Rescue equipment shall be available.

- Weather and flow conditions shall be monitored.
- Workers shall not enter high-flow areas without authorization.

Hazardous Materials Management

- Safety Data Sheets (SDS) shall be available.
- Hazardous materials shall be properly labelled.
- Storage areas shall have impermeable floors and bunds.
- Spill kits shall be maintained.
- Workers shall receive handling training.

Fire Prevention and Control

- Fire extinguishers shall be installed at strategic locations.
- Flammable materials shall be properly stored.
- Smoking shall be prohibited in designated areas.
- Emergency evacuation routes shall be marked.
- Fire drills shall be conducted periodically.

Housekeeping and Welfare Facilities

- Worksites shall remain clean and organized.
- Waste shall be regularly collected and disposed.
- Adequate drinking water shall be provided.
- Sanitary facilities shall be maintained.
- Rest areas and dining facilities shall be provided.

Landslide and Slope Stability Safety

- The Contractor shall implement slope stability and landslide risk management measures in excavation areas, tunnel portals, muck disposal sites, and access roads.
- Measures shall include:
- regular slope inspections;
- monitoring during monsoon periods;
- implementation of slope stabilization and drainage measures;
- restriction of work in unstable areas;
- emergency preparedness and evacuation procedures where required.
- Monitoring shall include evidence of slope instability, drainage condition, and corrective actions implemented.

OCCUPATIONAL HEALTH MANAGEMENT

Medical Screening

- Workers shall undergo:
- Pre-employment medical examinations;
- Periodic health check-ups;
- Return-to-work assessments where necessary.

Communicable Disease Prevention

- Measures shall include:
- Awareness and hygiene training;
- Vector control measures;
- Camp sanitation management;
- Isolation procedures where required;
- Coordination with local health authorities.

Heat and Cold Stress Management

- Adequate hydration shall be ensured.
- Rest breaks shall be scheduled.
- Weather conditions shall be monitored.
- Appropriate clothing shall be provided.

Dust, Noise and Vibration Control

- Water spraying shall be conducted on dusty surfaces.
- Dust masks shall be provided.
- Noise-producing equipment shall be maintained.
- Hearing protection shall be mandatory in high-noise areas.
- Exposure durations shall be minimized.

Climate and Extreme Weather Safety

The Contractor shall monitor weather conditions and implement safety measures during heavy rainfall, flash floods, thunderstorms, and other extreme weather conditions. High-risk activities shall be suspended during unsafe conditions, particularly near rivers, steep slopes, and excavation areas.

Community Health and Safety Assessment

Prior to commencement of construction, the Contractor shall prepare a **Community Health and Safety Assessment** as part of the CESHSMP consistent with ADB SPS (2009), IFC General EHS Guidelines, and Good International Industry Practice.

The assessment shall include, at minimum:

- population-at-risk mapping
- identification of sensitive receptors
- blast vibration zoning
- fly-rock hazard assessment
- traffic safety risk assessment
- flood inundation modelling
- emergency evacuation routes
- community warning systems
- public consultation and disclosure
- cumulative community safety risks associated with construction activities

Appropriate mitigation measures shall be incorporated into the Contractor's Community Health and Safety Management Plan before commencement of works.

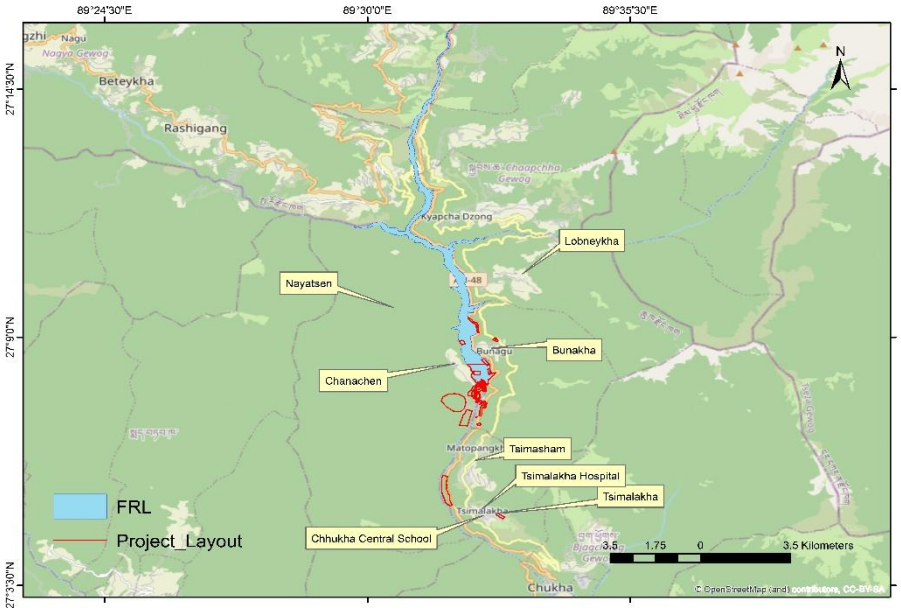


Figure 81: *Population-at-Risk Map - BHPP*

*The Contractor shall review, verify, and update the Population-at-Risk Map prior to commencement of any construction works

13.5.19.10 Training and Awareness

The Contractor shall implement an OHS training program including:

- Site induction training;
- Task-specific safety training;
- Toolbox talks;
- Emergency response training;
- First aid training;
- Fire safety training;
- Specialized training for high-risk works.

- Training records shall be maintained.

Fatigue Management

The Contractor shall implement fatigue management measures including adequate rest periods, controlled working hours, worker rotation, and monitoring of fatigue-related risks, particularly for tunnelling, night work, and remote construction activities.

Mental Health and Psychosocial Wellbeing

The Contractor shall promote worker wellbeing through awareness programs, worker grievance mechanisms, prevention of workplace harassment and discrimination, and provision of adequate welfare and accommodation facilities.

Life Saving Rules

The Contractor shall establish and enforce Project Life Saving Rules for all personnel working on the Project.

At a minimum, the Life Saving Rules shall address:

- working at height
- Confined space entry
- Permit-to-work compliance
- Lifting operations
- Excavation safety
- Blasting safety
- Safe driving
- Use of personal protective equipment
- Prohibition of alcohol and illicit drugs at work

All personnel shall receive training on the Project Life Saving Rules during induction and refresher training.

Permit to Work System

Permit-to-work procedures shall be implemented for:

- Hot work;
- Confined space entry;
- Excavation works;
- Electrical isolation;
- Work at height;
- Blasting operations;
- Heavy lifting activities.
- Permits shall specify:
- Scope of work;
- Hazards;
- Required controls;
- Responsible personnel;

- Validity duration.

Job Hazard Analysis (JHA) and Method Statements

The Contractor shall prepare Job Hazard Analyses (JHA), Task Risk Assessments (TRA), and Method Statements for high-risk activities including tunnelling, blasting, excavation, confined space entry, work at height, lifting operations, and electrical works prior to commencement of activities.

13.5.19.11 Incident Reporting and Investigation

All incidents, including near misses, shall be reported immediately.

Reportable Incidents

The following incidents and events shall be reported, recorded, investigated, and managed in accordance with the Project's Incident Reporting and Investigation Procedure:

- Fatalities (worker or third party)
- Permanent disability
- Medical Treatment Cases
- Near Misses
- High Potential Incidents (HiPo) with the potential to result in serious injury, fatality, or major property or environmental damage
- Occupational illnesses and work-related diseases
- Fire and explosion incidents
- Blasting-related incidents, including misfires, fly-rock events, excessive vibration, and unauthorized detonations
- Electrical shock and electrocution incidents
- Confined space incidents
- Collapse of excavations, tunnels, scaffolding, or temporary structures
- Falls from height
- Vehicle, traffic, and heavy equipment accidents
- Hazardous material and chemical spills affecting worker safety
- Dangerous occurrences requiring emergency response
- Property damage and equipment damage
- Security incidents affecting worker safety
- Community health and safety incidents associated with Project activities
- Environmental incidents that present actual or potential risks to worker or public safety
- Any incident required to be reported under applicable Bhutanese legislation, contractual requirements, or lender requirements.

Investigation Requirements

Investigations shall:

- Identify root causes
- Recommend corrective actions
- Assign responsibilities
- Track closure of corrective measures

- Incident statistics shall be compiled and analyzed monthly

13.5.19.12 Emergency Preparedness and Response

Potential Emergency Situations

Potential emergencies include:

- Tunnel collapse
- Fire and explosion
- Flooding and flash floods
- Slope failure and landslide
- Major accidents and injuries
- Hazardous material spills
- Electrical shock incidents
- Blasting accidents
- Vehicle accidents

Emergency Response Measures

The Contractor shall:

- Prepare site-specific Emergency Response Plans;
- Maintain emergency contact lists;
- Establish emergency communication systems;
- Provide first aid facilities and trained responders;
- Conduct mock drills periodically;
- Coordinate with local emergency services.

First Aid and Medical Facilities

- First aid stations shall be established.
- Ambulances or emergency transport shall be available.
- Trained first aid personnel shall be present at worksites.
- Emergency medical evacuation procedures shall be established.

Tunnel Emergency Preparedness and Rescue

The Contractor shall establish tunnel emergency preparedness procedures, including emergency communication systems, evacuation routes, rescue equipment, trained response personnel, and periodic emergency mock drills for underground works.

13.5.19.13 Workers' Camp Health and Safety

The Contractor shall ensure:

- Adequate accommodation standards;
- Separate and secure facilities for male and female workers;
- Fire safety provisions;
- Safe drinking water;
- Proper sanitation and drainage;

- Vector and pest control;
- Waste management systems;
- Food hygiene standards.

13.5.19.14 Contractor Management

All subcontractors shall:

- Comply with this OHS Plan;
- Participate in induction training;
- Submit method statements and risk assessments;
- Maintain competent supervision;
- Report incidents and corrective actions.
- Contractor OHS performance shall be included in the contractor evaluation.

Visitor Health and Safety

Visitors entering construction sites shall comply with all applicable Project health and safety requirements.

The Contractor shall ensure that visitors:

- receive a site safety induction
- wear appropriate personal protective equipment
- remain under the supervision of authorized personnel
- are restricted from entering high-risk work areas unless specifically authorized
- are recorded in visitor entry and exit registers.

Special precautions shall be implemented for official inspections, community visits, and stakeholder consultations conducted within active construction areas.

13.5.19.15 Implementation and Monitoring Matrix

Table 99: Implementation and Monitoring matrix

SN	Activity / Issue	Potential OHS Risk / Impact	Mitigation / Management Measures	Monitoring Indicators	Location	Timing / Frequency	Responsibility
1	Site Mobilization and General Construction Activities	Unsafe work practices, worker injury, unauthorized access	Prepare site-specific safety procedures; install barricades and signage; conduct inductions and toolbox talks; restrict unauthorized entry	Availability of signage and barricades; induction records; toolbox talk records	All construction sites	Throughout construction	Contractor / Safety Officer
2	Personal Protective Equipment (PPE)	Head injury, foot injury, eye injury, exposure to hazards	Provide task-specific PPE including helmets, gloves, safety shoes, high visibility vests, goggles, and hearing protection; enforce PPE use	PPE compliance rate; PPE issuance records	All work areas	Daily	Contractor / Safety Officer
3	Excavation and Trenching Works	Excavation collapse, falls, burial, water accumulation	Implement benching/sloping where feasible; use shoring where required; provide ladder access; barricade trenches; conduct daily inspection; install dewatering pumps where necessary	Excavation inspection records; presence of shoring and barricades; safe access availability	Excavation and foundation areas	Daily during excavation	Contractor / Safety Officer
4	Tunnel and Underground Works	Tunnel collapse, poor ventilation, oxygen	Maintain tunnel ventilation; install ground support systems; conduct gas monitoring; establish	Gas monitoring records; ventilation functionality; tunnel inspection reports	Tunnel and underground works	Daily	Contractor / Tunnel Safety Team

SN	Activity / Issue	Potential OHS Risk / Impact	Mitigation / Management Measures	Monitoring Indicators	Location	Timing / Frequency	Responsibility
		deficiency, gas exposure	emergency escape procedures; maintain communication systems				
5	Blasting Operations	Fly rock, vibration, premature explosion, injury	Restrict blasting to licensed personnel; establish exclusion zones; communicate blasting schedule; inspect blast areas before re-entry; maintain explosive inventory records	Blasting records; exclusion zone compliance; incident records	Quarry and blasting sites	During blasting activities	Contractor / Blasting Specialist
6	Working at Height	Falls from height, serious injury, or fatality	Implement work-at-height permit system; provide full body harnesses; install guardrails and lifelines; inspect scaffolds and ladders	Harness use; scaffold inspection records; permit records	Elevated work locations	Daily	Contractor / Safety Officer
7	Machinery and Heavy Equipment Operation	Collision, struck-by incidents, rollover accidents	Allow only trained operators; maintain equipment inspection and preventive maintenance records; install reversing alarms; deploy spotters where necessary	Equipment inspection logs, operator licenses, and maintenance records	Construction sites and haul roads	Daily / Weekly	Contractor / Mechanical Team
8	Electrical Works	Electric shock, electrocution, fire	Implement lockout/tagout procedures; maintain grounding systems; restrict access to electrical panels; inspect cables regularly	Electrical inspection records; grounding status; damaged cable observations	Electrical work areas	Weekly	Contractor / Electrical Team

SN	Activity / Issue	Potential OHS Risk / Impact	Mitigation / Management Measures	Monitoring Indicators	Location	Timing / Frequency	Responsibility
9	Traffic and Transportation	Vehicle accidents, collision with workers or public	Implement Traffic Management Plan; enforce speed limits; use flag persons; conduct driver training and vehicle inspection	Vehicle inspection records; speed monitoring; driver training records	Access roads and haul roads	Daily	Contractor / Transport Supervisor
10	River and Water Related Works	Drowning, slipping, flooding incidents	Provide life jackets; restrict work during high flows; maintain rescue equipment; monitor weather and river conditions	Availability of rescue equipment; life jacket compliance	River crossing and diversion areas	Daily during river works	Contractor / Safety Officer
11	Hazardous Materials and Fuel Storage	Chemical exposure, spills, fire risk	Store chemicals in bunded areas with impermeable floors; maintain SDS; provide spill kits; train workers on chemical handling	Storage condition, spill response equipment, SDS availability	Fuel storage and workshops	Weekly	Contractor / Environmental and Safety Team
12	Dust Generation and Air Quality	Respiratory illness, reduced visibility	Conduct water spraying; cover transported materials; provide dust masks; limit exposure duration	Dust suppression records; worker PPE compliance	Roads, excavation, and muck areas	Daily	Contractor
13	Noise and Vibration	Hearing damage, worker discomfort	Maintain equipment; provide hearing protection; restrict exposure duration in high-noise areas	Hearing protection compliance; equipment maintenance records	High-noise work areas	Daily	Contractor
14	Fire Prevention and Emergency Preparedness	Fire outbreak, injury, property damage	Install fire extinguishers; establish evacuation routes; conduct fire drills; restrict smoking in hazardous areas	Fire extinguisher inspection records; drill records	Camps, workshops, and fuel storage areas	Monthly / Quarterly	Contractor / Safety Officer

SN	Activity / Issue	Potential OHS Risk / Impact	Mitigation / Management Measures	Monitoring Indicators	Location	Timing / Frequency	Responsibility
15	Workers' Camp Health and Safety	Disease outbreak, poor sanitation, fire risk	Maintain clean accommodation; provide potable water and sanitation; implement waste management; maintain separate secure accommodation for male and female workers	Camp inspection records; sanitation condition; waste management compliance	Workers' camps	Weekly	Contractor / Camp Manager
16	Occupational Health Monitoring	Occupational illness, fatigue, communicable disease	Conduct medical checkups; provide first aid facilities; conduct awareness programs; monitor heat/cold stress and fatigue	Medical records, first aid availability, and awareness training records	Camps and worksites	Monthly / Periodic	Contractor / Medical Team
17	Emergency Response and Incident Management	Delayed response to accidents and emergencies	Prepare Emergency Response Plan; maintain emergency contacts; conduct mock drills; report and investigate incidents	Incident records, emergency drill records, and corrective action closure	All project sites	Monthly / Quarterly	Contractor / OHS Manager
18	Training and Capacity Building	Unsafe behavior due to inadequate awareness	Conduct induction training, toolbox talks, specialized safety training, and refresher training	Training attendance records; toolbox talk records	All project sites	Ongoing	Contractor / OHS Team
19	Landslide and Slope Stability Monitoring	Landslide, slope failure, rockfall	Conduct slope inspections, monitor rainfall conditions, implement stabilization measures, and restrict work in unstable areas	Slope inspection records, evidence of instability, and corrective actions	Excavation areas, muck disposal sites, tunnel portals, access roads	During construction and monsoon periods	Contractor / Geotechnical Engineer / Safety Officer

Monitoring Parameters

Table 100: Monitoring parameters

Monitoring Aspect	Indicators	Frequency	Responsible
PPE Compliance	Proper PPE use	Daily	Safety Officer
Housekeeping	Site cleanliness	Daily	Supervisor
Excavation Safety	Barricades, slope stability	Daily	Safety Officer
Machinery Safety	Inspection and maintenance	Weekly	Mechanical Team
Electrical Safety	Cable and panel inspection	Weekly	Electrical Team
Fire Safety	Extinguisher availability	Monthly	Safety Officer
Training	Number of trainings/toolbox talks	Monthly	OHS Manager
Incident Reporting	Number and type of incidents	Monthly	OHS Manager
Medical Facilities	Availability and adequacy	Monthly	Camp Manager
Emergency Preparedness	Mock drills conducted	Quarterly	OHS Team

OHS Performance Indicators

The Contractor shall monitor key OHS indicators, including fatalities, lost time injuries, PPE compliance, emergency drills, training coverage, near-miss reporting, and corrective action closure. Monthly OHS performance reports shall be submitted to ESHS and supervising consultants.

13.5.19.16 OHS performance targets

The Contractor shall establish measurable Occupational Health and Safety performance targets consistent with Project objectives and international good industry practice.

Performance indicators shall include, where applicable:

Performance Indicator	**Target**
Fatalities	Zero
Lost Time Injuries	Continuous reduction
High Potential Incidents	Immediate investigation and corrective action
Near Miss Reporting	Increasing reporting culture
PPE Compliance	≥98%
Toolbox Talks	Daily
Safety Inspections	Weekly
Emergency Drills	Minimum quarterly
Corrective Action Closure	Within agreed timeframe
Training Completion	100% of applicable personnel

Performance shall be reviewed regularly by the Contractor and reported to DGPC as part of routine health and safety reporting.

13.5.19.17 Auditing and Review

Internal OHS audits shall be conducted periodically to assess:

- Compliance with the OHS Plan;
- Effectiveness of mitigation measures;
- Implementation gaps;
- Training effectiveness;
- Incident trends.
- Corrective and preventive actions shall be tracked until closure.

13.5.19.18 Documentation and Record Keeping

The following records shall be maintained:

- Training records
- Inspection reports
- Incident reports
- Medical records
- PPE issuance records
- Equipment inspection logs
- Permit-to-work records
- Emergency drill records
- Audit reports.

13.5.19.19 Continual Improvement

The OHS Plan shall be reviewed and updated periodically based on:

- Incident investigation findings
- Audit observations
- Regulatory changes
- Lessons learned
- Changes in construction activities
- Stakeholder feedback.

13.5.19.20 OHS Budget (Construction Phase)

Table 101: OHS budget

SN	OHS Component	Unit / Basis	Estimated Budget (BTN/Nu.)
1	OHS Staffing (OHS Manager, Safety Officers, Medics)	Lump Sum (Annual)	8,500,000

2	PPE Procurement and Replacement	Helmets, shoes, gloves, harnesses, vests, etc.	6,000,000
3	Safety Signage, Barricades and Site Demarcation	Construction sites and access roads	1,500,000
4	Excavation Safety Measures	Shoring, trench supports, ladders, dewatering pumps	3,500,000
5	Tunnel and Underground Safety Systems	Ventilation, gas monitoring, and escape systems	7,000,000
6	Blasting Safety Management	Blast warning systems, exclusion controls	2,000,000
7	Fire Prevention and Emergency Equipment	Fire extinguishers, alarms, rescue kits	2,500,000
8	First Aid and Medical Facilities	First aid stations, medicines, and ambulance support	2,000,000
9	Occupational Health Monitoring	Medical checkups and health screening	1,500,000
10	OHS Training and Capacity Building	Inductions, toolbox talks, mock drills	1,200,000
11	Traffic and Road Safety Measures	Flag persons, road signs, speed controls	1,000,000
12	River Safety Measures	Life jackets, rescue equipment	800,000
13	Hazardous Materials and Spill Management	Spill kits, storage improvements, SDS management	1,000,000
14	Workers' Camp Health and Safety	Sanitation, potable water, and camp inspections	2,500,000
15	Monitoring, Inspection, and Audits	Routine inspections and third-party audits	1,500,000
16	Emergency Preparedness and Mock Drills	Periodic drills and emergency exercises	700,000
17	Contingency (Approx. 10%)	Unforeseen OHS requirements	4,120,000
	Total Estimated Budget		**45,320,000**

Notes: Budget estimates are indicative and shall be refined during detailed construction planning and contractor mobilization. Costs may vary depending on contractor methodology, workforce size, tunnel length, and construction duration. The Contractor shall include OHS implementation costs within the overall project construction budget and BOQ.
Emergency medical evacuation and specialized rescue arrangements for underground works may require additional allocation depending on the final design and site conditions.

The implementation of this Occupational Health and Safety (OHS) Plan shall support the safe execution of construction activities associated with the Bunakha HPP while minimizing occupational risks to workers, contractors, visitors, and associated personnel.

The Contractor, BHPL, supervising consultants, and all workers shall share responsibility for ensuring compliance with this OHS Plan and promoting a proactive safety culture throughout project implementation.

13.5.20 Decommissioning plan

To ensure that the project construction facilities do not pose any long-term environmental or safety risks, appropriate decommissioning measures will be implemented after the completion of construction works. The objective of the decommissioning plan is to restore the affected areas to a stable and environmentally acceptable condition and to ensure that no residual impacts remain on land, water resources, or landscape aesthetics.

Since most of the temporary construction facilities are located within the reservoir inundation area, such facilities will either be dismantled and removed prior to reservoir impoundment or cleared to a level that will not affect reservoir operation, water quality, or safety.

**Facilities outside the inundation area: fully dismantled and restored*

**Facilities inside the inundation area: dismantled to safe level before reservoir impoundment*

Table 102: Potential impacts

Impact Category	Description
Soil Contamination	Residual contamination from fuel storage, oil spills, chemical handling, and hazardous waste
Water Quality Degradation	contaminants, or untreated waste into water bodies during dismantling
Air Pollution	Dust generation from dismantling activities, debris handling, and vehicle movement
Waste Generation	Large quantities of construction debris, scrap metal, hazardous waste, and domestic waste requiring disposal
Habitat Disturbance	Disruption to regenerated vegetation and wildlife during dismantling activities
Landscape Degradation	Altered topography, exposed foundations, and visual scars if restoration incomplete
Safety Hazards	Risks to workers and public from unstable structures, remnants, and hazardous materials

Following measures shall be undertaken during the demobilization phase.

Contractor's Labor Camps 1 and 2 (Inside inundation area)

Upon completion of construction works, all temporary labour camps shall be dismantled and removed.

The following measures shall be implemented:

- All temporary buildings, sanitation facilities, kitchens, storage sheds, and utilities shall be deconstructed and removed from the site.
- Solid waste, scrap materials, and unused construction materials shall be collected and disposed of at approved waste management facilities.
- Septic tanks and soak pits shall be emptied, cleaned, filled with suitable material, and covered to avoid environmental contamination.
- Any contaminated soil resulting from improper waste handling shall be removed and properly disposed of.

CCF- material, storage, offices, lab, workshops and stock pile area - 2 (Inside Inundation Area)

Facilities located within the reservoir inundation area shall be dismantled completely and cleared before reservoir filling to prevent deterioration of water quality and obstruction within the reservoir.

The following measures shall be taken:

- All mechanical equipment, repair sheds, fuel storage tanks, and maintenance facilities shall be dismantled and removed from the project area.
- Oil interceptors, fuel storage areas, and contaminated soils shall be cleaned and remediated where necessary.
- Scrap metals, used oils, and hazardous materials shall be collected and disposed of in accordance with environmental regulations of Bhutan.

CVC Batching Plant, RCC batching Plant, Stock Pile Area – 1, H&M Store, and E&M Store (Outside Inundation Area)

Upon completion of construction works, the contractor shall dismantle and demobilize all batching plants, crushing plants, and aggregate processing facilities. The following measures shall be undertaken:

- All plant structures, foundations, machinery, conveyors, and storage facilities shall be dismantled and removed from the site.
- Residual construction materials, cement dust, lubricants, and debris shall be cleared and disposed of at approved disposal locations.
- Contaminated soils, if any, caused by fuel, oil, or chemical spills shall be removed and treated in accordance with environmental management guidelines or disposed at appropriate location.
- Areas shall be graded, stabilized, and restored to natural landforms as far as practicable.
- Dust suppression measures shall be applied during dismantling activities to minimize air pollution.

Access Roads (Partially Outside of Inundation Area) and Temporary Infrastructures

Temporary access roads constructed solely for construction activities shall be rehabilitated where they are not required during project operation.

- Temporary roads not required for operation and maintenance shall be cleared of debris and unnecessary structures.
- Road surfaces shall be stabilized and revegetated to prevent soil erosion.
- Drainage structures shall be restored to ensure natural drainage patterns.
- Portions of roads located within the reservoir inundation area will be allowed to submerge after clearing of debris and unstable materials.

**Parts of the Highway/Road which may have suffered damage due to use during project construction stage will be repaired in consultation/coordination with the relevant agencies.*

Explosive Magazine (Outside Inundation Area)

The following measures shall be undertaken during decommissioning:

- Prior to dismantling, all remaining explosives, detonators, and blasting accessories shall be safely removed and returned to authorized suppliers or transferred to approved storage facilities in accordance with regulations of the Royal Government of Bhutan.
- The magazine structures, including storage buildings, security fencing, lightning protection systems, guard shelters, and ancillary facilities shall be dismantled and removed from the site.
- The magazine area shall be thoroughly inspected for any explosive residues, detonator fragments, or hazardous materials, and such materials shall be safely collected and disposed of following applicable safety regulations.
- Concrete foundations and structural remains shall be demolished and removed unless otherwise approved by the Engineer and relevant authorities.
- The disturbed land shall be graded to natural contours and rehabilitated through soil stabilization and revegetation using native plant species.

Decommissioning of explosive magazines shall be carried out in compliance with the applicable national explosive safety regulations and guidelines and under the supervision of the relevant regulatory authorities.

BHPL Temporary Office (Outside Inundation Area)

- All temporary office buildings and related structures shall be dismantled.
- Structural components (metal frames, wooden panels, roofing sheets, etc.) shall be segregated for reuse, recycling, or proper disposal.
- Temporary electrical, plumbing, and communication connections shall be safely disconnected and removed.
- All furniture, office equipment, stationery, and miscellaneous materials shall be removed.
- Waste materials, including plastics, and non-reusable items, shall be collected and disposed of at authorized waste management facilities.
- Any hazardous materials (paints, lubricants, batteries, cleaning chemicals) shall be removed and disposed of according to environmental and safety regulations.
- The site shall be cleared of debris, rubble, and leftover construction materials.
- Disturbed areas shall be leveled and prepared for natural vegetation or alternative land use as per the landowner agreement.

- Topsoil, if removed during construction, shall be reapplied to support re-vegetation.
- Temporary toilets, septic tanks, and soak pits shall be decommissioned: emptied, cleaned, and filled with suitable material.
- Drainage and wastewater management systems shall be dismantled, and the area restored to natural contours.

Table 103: Monitoring Plan

Facility/Location	Monitoring Parameter	Frequency	Responsible Party	Documentation
Facilities Inside Inundation Area	Structure removal completion; waste disposal; sanitation pit decommissioning; contamination cleanup	Before reservoir filling	Contractor Engineer Environment Officer	Clearance certificate waste disposal receipts photographic records soil testing reports
Facilities Outside Inundation Area	Site clearance; soil restoration; waste disposal; hazardous material removal; grading completion	During dismantling; post-completion	Contractor Engineer Environment Officer	Inspection reports restoration completion certificate material recycling records
Explosive Magazine	Explosive removal; structure dismantling; residue inspection; land rehabilitation	During dismantling; post-completion	Contractor ESHS	Explosive transfer certificates inspection reports clearance from authorities
Access Roads	Road rehabilitation; erosion control; drainage restoration	Post-completion; first monsoon	Contractor Engineer Environment Officer	-
Waste Disposal Sites	Waste acceptance; disposal compliance	Per disposal event	Contractor Engineer Environment Officer	Disposal receipts transport records

Rehabilitation and Landscape Restoration

Following demobilization of all temporary facilities:

- All disturbed areas outside the reservoir area shall be graded and restored to stable landforms.
- Topsoil shall be reapplied wherever available to support vegetation growth.

- Native vegetation shall be planted to facilitate ecological restoration as per Biodiversity Management Plan.

**All decommissioning activities shall be carried out under the supervision and approval of the Engineer.*

Budget

The cost associated with decommissioning and site restoration activities shall be included within the contractor's scope of work and implemented as part of the environmental management obligations under the project.

13.5.21 Blasting operation plan

Blasting operations will be necessary during the pre-construction and construction stages of the BHPP for excavation of dam foundation, diversion tunnels, powerhouse complex, and quarry.

To manage the blasting requirements, one permanent mother explosive magazine (27° 7'13.96"N, 89°32'16.83"E) will be established at the Chanachen farm road junction with the highway, covering a total area of 0.37 acres, comprising of state reserved forest land.

The Contractor shall comply fully with all requirements, standards, protocols, and mitigation measures specified in this Section 13.5.21, and shall treat this Blasting Operation Plan as the primary and binding governing document for all blasting and explosives-related activities at the site.

Table 104: Potential Impacts

Impact Type	Description	Affected Area
Noise	High-intensity noise from blasting affects wildlife, communities, and sensitive receptors	Bunakha Lhakhang, Lamche Bja, communities within 500m
Vibration	Ground vibration from blasting can damage structures and affect geological stability	Lamche Bja, Bunakha Lhakhang, structures within 500m
Dust/Air Pollution	Dust generation affecting air quality and deposition on vegetation	Downwind areas including Lobnekha Heritage Village
Fly Rock	Dispersal of rock fragments beyond blast area	Areas within 500m exclusion zone
Safety Hazards	Risks to workers and nearby communities from blast effects	Blast site and surrounding areas

Table 105: Sensitive Receptors

Receptor	Distance/Location
Bunakha Lhakhang	Eastern riverbank
Lamche Bja (Elephant Cliff)	Upslope from proposed quarry
Lobnekha Heritage Village	8-10 km north-northeast (downwind)
Communities within 500m	Communities

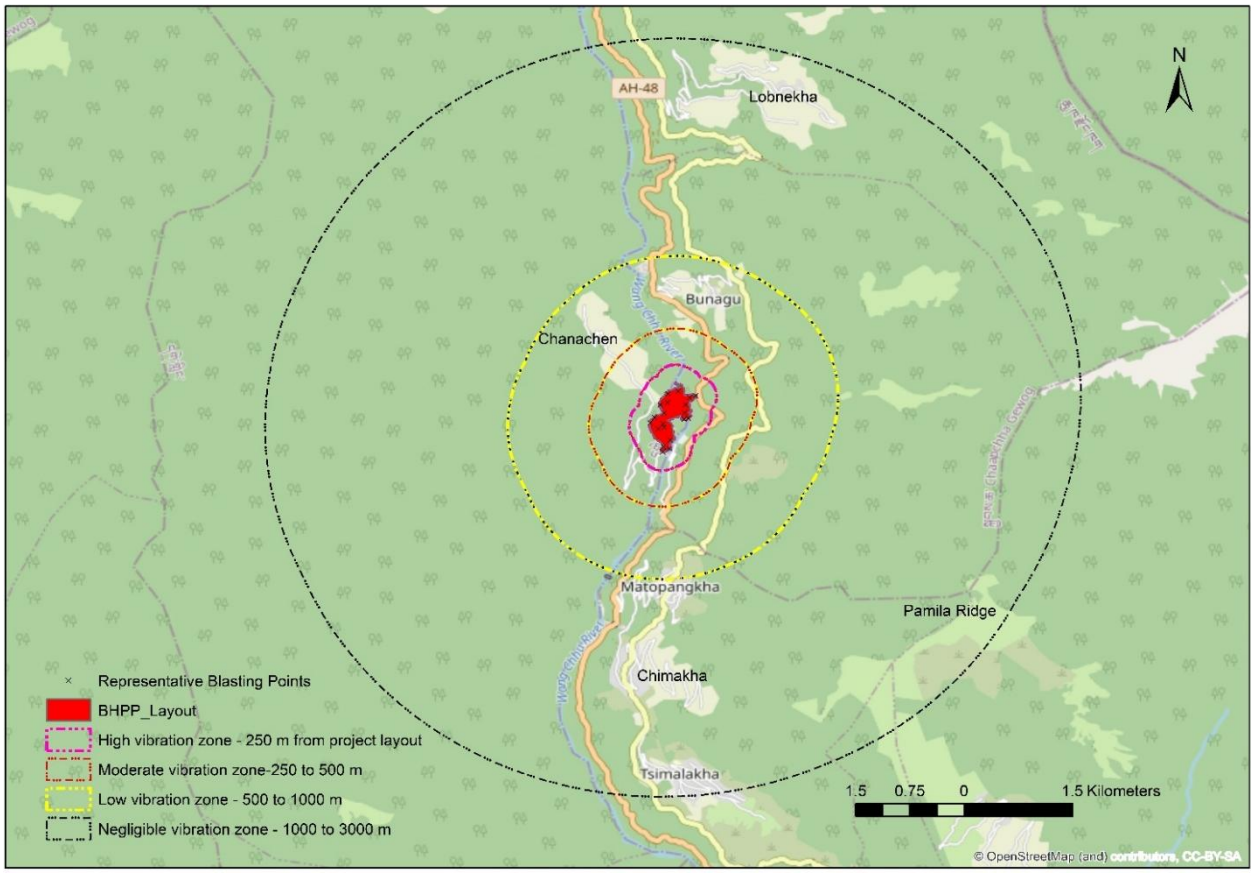


Figure 81: Map indicating the potential area of influence due to blasting

** This map is an indicative planning map and shall not be interpreted as representing regulatory limits.*

13.5.21.1 Blasting Details

13.5.21.1.1 Blasting Methodology

- Charging of drilled holes using emulsion and Non-Electric Detonator.
- After studying site, quantity of explosives will be approved by Engineer In-Charge in consultation with geologist and licensed blaster.
- Each hole, except dummy holes, will be charged
- Explosives producing less than 0.005 cum of poisonous gas per 1.25" x 8" cartridge shall be used

13.5.21.1.2 Storage Requirements:

All explosives shall be stored in a secure place in compliance with all laws and ordinances of the Royal Government of Bhutan.

The following instructions shall be observed:

Location: Explosives shall be stored in closed containers or buildings to the satisfaction of the Engineer and located not closer than 500 m from any buildings, camping areas, or places of human occupancy. Separated storage container/buildings will be installed for explosive and detonators as those products must never be stored together.

Security: Site will be fully fenced and access controlled 24/7. No unauthorized persons shall be admitted into the boundary of portable magazines, which shall be kept under lock and key when not in use.

Fire Prevention: No match boxes or inflammable materials shall be allowed within the premises of the portable magazine

Lightning Protection**:** An appropriate lightning arrangement shall be provided at the portable magazine site.

Signage: All storage places and portable magazines shall be clearly marked with warning signs.

**The area for the storage of explosives shall be built as per the specifications of the RGoB laws in place and located at a site approved by the Engineer.*

13.5.21.1.3 Controlled Blasting

Blasting will be carried out in a manner that avoids wide dispersal of flying rocks and do not trigger landslides. Experiences gained from implementation of previous hydropower projects will be used in implementation of BHPP.

Simultaneous blasting using detonating cord will be adopted. This will prevent flying rocks, thus keeping broken rocks in one place through the phenomenon called “pushing against one another” (this causes the percussive force of simultaneous blasts to counter against each other, reducing rock dispersal).

13.5.21.1.4 Blasting Operations

- Blasting will be conducted only by certified blasting personnel under the supervision of a qualified Blasting Engineer.
- Detailed blast design and charge calculations will be prepared for each blasting operation.
- Blasting will be carried out during designated daytime hours to reduce disturbance to nearby communities.
- Warning signals and sirens will be used prior to blasting.
- A safety perimeter will be established to prevent unauthorized entry into blasting zones.

13.5.21.1.5 Blasting Signals

All blasting operations shall be conducted during daytime hours only, avoiding early morning and night periods when visibility is poor and wildlife is active. Local communities will be notified at least 24-48 hours in advance of scheduled blasting activities, with information on date, time, and duration provided through community liaison officers and local representatives. Standard warning signals, including sirens, will be used before each blast to alert communities and ensure public safety.

Table 106: Blasting signals

Signal	Description	Timing
First Warning	Long continuous siren	5 minutes before blast
Second Warning	Two short sirens	1 minute before blast
Blast	Actual blast	-
All Clear	Long continuous siren	After post-blast inspection

13.5.21.2 Baseline Infrastructure Survey

13.5.21.2.1 Pre-Blast Documentation

A comprehensive data collection and mapping program for structures near prospective blast zones shall be undertaken:

- Identify all buildings, structures, and infrastructure within 500m of blast areas
- Conduct detailed photographic documentation of existing conditions
- Record any pre-existing cracks, damages, or structural issues
- Maintain inventory with property owner acknowledgments

13.5.21.2.2 Post-Blast Monitoring

- Conduct visual inspections after each major blast series
- Document any changes or new damages

- If concerns or claims arise, pre-blast photographs shall be consulted to objectively determine possible effects from project blasting

Table 107: Environmental Management Measures

Aspect	Mitigation Measures
Dust Control	Water spraying will be conducted before and after blasting to reduce dust emissions Blasting operations will avoid periods of strong winds to limit dust dispersion
Noise Management	Controlled blasting techniques will be applied to reduce excessive noise Blasting will be scheduled during daytime hours only
Vibration Control	Charge size and delay timing will be optimized to minimize ground vibration Blasting vibration will be monitored where sensitive structures or settlements exist nearby
Fly Rock Prevention	Proper stemming and blasting techniques will be applied Blasting mats or protective measures may be used where necessary
Occupational Health and Safety	Workers involved in blasting operations will receive specialized safety training Personal protective equipment (PPE) including helmets, safety goggles, gloves, ear protection, and safety boots will be mandatory First aid facilities and emergency response equipment will be available at blasting sites A blast clearance procedure will be followed before and after each blast

Table 108: Blasting Operation Monitoring Plan

Monitoring Aspect	Parameters	Location	Frequency	Responsible Party	Records / Documentation
Vibration Monitoring	Peak Particle Velocity (PPV) and frequency	Bunakha Lhakhang, Lamche Bja (Elephant Cliff), structures within 500m of blast zones (if present)	Each blast	Contractor BHPL	Vibration monitoring reports; predictor equation development
Fly Rock Inspection	Distance of rock dispersal; penetration beyond exclusion zone	Exclusion zone perimeter (500m radius)	Each blast	ESHS	Fly rock observation log; incident reports if exceeded
Dust Monitoring	Visible dust emissions; air quality	Downwind areas, nearby communities	During blasting operations	Contractor Environmental Officer	Dust observation records; community complaint register
Explosive Inventory	Daily consumption; balance stock	Mother magazine and portable magazines	Daily	Project Manager Contractor	Daily consumption register; balance sheet records
Blast Design Compliance	Charge per delay; hole spacing; stemming length	Blast site	Each blast	Blasting Engineer Geologist	Blast design approval sheets; as-built blast records
Warning Signal Effectiveness	Audibility; community awareness	Communities within 1km radius	Each blast	Community Liaison Officer Blaster	Signal test records; community feedback log
Safety Perimeter	Unauthorized entry; clearance confirmation	Exclusion zone (500m radius)	Before each blast	OHS Officer	Clearance certificate; access control log

Monitoring Aspect	Parameters	Location	Frequency	Responsible Party	Records / Documentation
Incident and Accident Reporting	Injuries; wildlife mortality; property damage; complaints	All blast sites	As occurring	Contractor OHS Officer	Incident reports; investigation reports; corrective action records
Regulatory Compliance	Adherence to Mines and Minerals Management Regulations, 2002	Magazine and blast sites	Monthly; during regulatory inspections	ESHS	Compliance checklists; inspection reports; approval letters
PPE Compliance	Usage of helmets, goggles, gloves, ear protection, safety boots	Blast site and magazine	Daily	OHS Officer	PPE inspection logs; non-compliance reports
First Aid Readiness	Availability of first aid facilities and emergency equipment	Blast site	Before each blast	OHS Officer	First aid checklist; equipment inspection records

13.5.21.3 Vibration Monitoring

The maximum blast induced ground vibration imposed by law in Bhutan (Mines and Minerals Management Regulations, 2002) shall be followed. Whenever any damage to private or public property or places of cultural heritage is reportedly caused by blast-induced ground vibration, the cost of rehabilitation will be borne by the CC. The CC will be required to carry out measurements of peak particle velocity (PPV) and frequency of the ground vibration induced by blasting and to develop a predictor equation for ground vibration for the site.

Install vibration monitors at sensitive locations including:

- Bunakha Lhakhang
- Lamche Bja (Elephant Cliff)
- Other structures within 500m of blasting zones

Monitor peak particle velocity (PPV) for each blast

Maintain vibration records for review by Engineer

13.5.21.4 Blasting Record

The following records shall be maintained at the site and shall be produced at the instruction of Engineer or competent authority of the RGOB:

- Copy of relevant rules regarding the storing, handling of the explosives.
- The daily consumption and balance sheet records of the explosives
- Notice prohibiting smoking in the restricted area.

13.5.21.5 Data on injuries and accidents

Each contractor will be required to report any accidents or damage to wildlife and other complaints/reports received due to blasting.

This must be submitted to project management to further enable management of risks due to blasting.

Additional Mitigation Measures

- Conduct trial blasts to optimize explosive charge weights, delay sequencing, and blast patterns.
- Restrict blasting during periods of intense rainfall when slope stability may already be compromised.
- Maintain blast records and vibration monitoring data to continuously refine blasting practices.

13.5.22 Crusher and batching plant operation

Following the completion of muck disposal in MD-1, the same area will be utilized for the establishment of crushing and batching plants. The Chanachen farm road shall be used as the primary road to access batching and crushing plant.

This operation plan outlines measures for the safe and environmentally responsible operation of crusher and batching plant during the construction of the BHPP.

The purpose of this plan is to:

- Ensure the efficient and safe production of aggregates, sand, and concrete for construction.
- Minimize air, water, noise, and land impacts during plant operations.
- Comply with national environmental standards, occupational health & safety regulations, and ADB safeguard requirements.
- Define operational, monitoring, and management responsibilities for the plants.

Table 109: Potential Impacts

Impact Category	Potential Impacts	Affected Receptors
Air Quality	Dust emissions from crushing, screening, and material handling Particulate matter (PM_{10}, $PM_{2.5}$) from stockpiles and haul roads Emissions from diesel generators and heavy equipment (SOx, NOx, CO) Cement dust from batching operations and silos Exacerbation of existing NO_2 exceedances (already above WHO guidelines) Dry season critical pollution episodes with $PM_{2.5}$ and O_3 formation	Chanachen village (primary hotspot) Downwind communities: Nayakha, Lobnekha Heritage Village Bunakha Lhakhang Plant workers Surrounding vegetation
Noise Pollution	High noise levels from crushers, screens, and conveyors Intermittent noise from batching plant operations Traffic noise from haul trucks and loaders Low-frequency noise propagation affecting quiet areas	Chanachen village (pristine acoustic environment - ANSP-10) Nayakha village (quietest area - 36.53 dBA night-time) Bunakha Lhakhang (cultural heritage site) Plant workers Wildlife in surrounding areas

Impact Category	Potential Impacts	Affected Receptors
Water Resources	Contamination of surface water from runoff containing sediments Pollution from concrete wash water and slurry Oil and fuel spills from equipment Increased turbidity in nearby streams Risk to community drinking water sources	Wangchhu River Local drainage channels Aquatic ecosystems Chanachen Village Spring Water (SW-10) Chomteykha Spring (SW-07)
Soil and Land	Soil contamination from fuel, oil, and chemical spills Soil erosion from exposed areas Loss of topsoil during site preparation Compaction from heavy equipment movement Risk of soil alkalization from cement spills	Plant site area (SSP-7, SSP-8) Adjacent agricultural land Surrounding forest areas
Waste Generation	Construction debris and packaging waste Hazardous waste (used oils, lubricants, chemical containers) Concrete waste and slurry Domestic waste from worker facilities	Plant site Disposal sites (as assigned by Bhutan Government) Surrounding environment
Occupational Health and Safety	Respiratory issues from dust inhalation Hearing loss from prolonged noise exposure Accidents from heavy equipment operation Injuries during material handling Exposure to hazardous chemicals	Plant workers Site visitors Maintenance personnel
Visual and Landscape	Visual intrusion from tall structures and stockpiles Night lighting impacts Landscape alteration	Chanachen village Bunakha Lhakhang (visibility concerns) Travelers on highway

13.5.22.1 Environmental Management Measures

Site Preparation and Layout

- Plants shall be located on leveled, compacted ground with proper drainage to prevent waterlogging.
- Stockpile areas for sand, aggregates, and cement shall be defined with bunds or retaining walls to prevent material runoff.
- Access roads within the plant site shall be provided for trucks and heavy equipment.
- Buffer zones of at least 100 m will be maintained between the plants and any watercourse or sensitive area.
- Wind barriers or fencing shall be installed to reduce dust spread to surrounding areas.

Table 110: Mitigation Measures

Aspect	Mitigation Measures
Air Quality Management	▪ Install and operate high-pressure water sprinklers on all conveyor belts, stockpiles, and haul roads continuously during dry season ▪ Apply water spraying at least twice daily during dry season; increase frequency during periods of high wind or low humidity ▪ Cover all stockpiles with tarpaulins or geo-textile covers during non-operational periods and high winds ▪ Conduct weekly ambient air monitoring at plant boundary and Chanachen village (ANSP-10) ▪ Monitor PM_{10}, $PM_{2.5}$, NOx, SO_x, and CO during both dry and wet seasons ▪ Provide dust masks or respirators (N95 or equivalent) for all workers in high-dust areas
Noise Management	▪ Equip all machinery with mufflers and silencers in good working condition ▪ Restrict night-time operations (22:00-06:00) completely near communities ▪ Schedule high-noise activities during daytime hours only ▪ Coordinate with community liaison officer to inform residents of scheduled activities ▪ Conduct weekly noise monitoring at plant boundary and sensitive receptors (Chanachen-ANSP-9, Nayakha-ANSP-10) ▪ Provide hearing protection (earplugs/earmuffs) with appropriate Noise Reduction Rating (NRR)
Water Management	▪ Construct network of drains and sedimentation pits to collect all runoff from plant areas ▪ Install oil-water separators at workshop and fueling areas ▪ Ensure all drainage systems are lined to prevent groundwater infiltration ▪ No untreated water or slurry shall enter natural watercourses under any circumstances ▪ Designate exclusion zones (minimum 50m buffer) around all community water sources (Chanachen Spring water-SW-10, Chomteykha Spring-SW-07) ▪ Provide bunded areas for fuel and chemical storage with 110% containment capacity
Soil Protection	▪ Compare results against baseline data (SSP-7, SSP-8) ▪ Preserve topsoil for final rehabilitation of all disturbed areas ▪ Conduct quarterly soil testing at high-risk areas (fuel storage, batching plant) for pH, heavy metals, and hydrocarbons

Aspect	Mitigation Measures
Waste Management	▪ Provide designated color-coded waste collection bins for different waste streams (hazardous, recyclable, general) ▪ Store hazardous wastes (oils, lubricants, chemicals) in dedicated bunded areas with impermeable flooring ▪ Maintain hazardous waste inventory and disposal records ▪ Dispose of hazardous wastes through authorized vendors only as per Bhutan Environmental Management Regulations ▪ Collect concrete wash water and slurry in settling tanks; never discharge to environment
OHS	Provide and enforce use of: helmets, safety shoes, goggles, gloves, hearing protection, dust masks
	Display safety signage in Dzongkha and English at all restricted areas, high-noise zones, and hazardous material storage
	Develop and implement site-specific Emergency Response Plan by contractor
Operational Control	Conduct pre-operational inspections of all equipment daily
	Maintain inspection logs and maintenance records
	Maintain stockpile heights within safe limits (maximum 10m)

Table 111: Monitoring Summary

Monitoring Aspect	Parameters	Location	Frequency	Responsibility
Air Quality	TSP, PM_{10}, $PM_{2.5}$, SOx, NOx, CO	Plant boundary; Chanachen (ANSP-10) Nayakha (ANSP-9)	Weekly (dry) Monthly (wet)	Environmental Officer
Noise Levels	Leq day, Leq night	Plant boundary Chanachen Nayakha Bunakha Lhakhang	Weekly	Environmental Officer
Water Quality	pH, turbidity, TSS, oil & grease,	Runoff discharge sedimentation pond community springs (SW-10, SW-07)	Monthly post-rain events	Environmental Officer
Soil Contamination	pH, heavy metals, TPH	Fuel storage Workshop batching and crushing plant	Quarterly	Environmental Officer
Waste Management	Volume disposal receipts	Plant site Waste storage areas	Daily	Contractor
Dust Deposition	Visible dust; dust fall	Chanachen Nayakha unakha Lhakhang	Daily (visual)	Environmental Officer
Equipment Condition	Leaks noise maintenance	All plant equipment	Daily pre-operation	Plant Supervisor
Spill Incidents	Occurrence response	Plant site	As occurring	Environmental Officer
Community Complaints	Noise, dust, vibration	Chanachen Nayakha Bunakha	As received	CLO

13.5.23 Quarry restoration plan

Quarry sites developed for extraction of rock and aggregate materials during the construction of the BHPP will be restored after completion of quarrying operations.

The restoration plan aims to minimize long-term environmental impacts, stabilize the disturbed land, and promote ecological recovery of the quarry areas.

As a dedicated ESIA is required by the RGoB, DGPC will be responsible for the preparation of the ESIA and the obtaining of the Environmental Clearance which will include a Quarry Management Plan. However, general outline of restoration plan is provided below:

13.5.23.1 Objectives

The key objectives of the quarry restoration plan are:

- Restore disturbed quarry areas to stable and environmentally acceptable conditions.
- Prevent soil erosion, landslides, and sediment transport into nearby water bodies.
- Ensure that the quarry sites do not pose long-term safety hazards to local communities or wildlife.

13.5.23.2 Site Preparation for Restoration

Upon completion of quarrying activities, the following measures will be implemented:

- Removal of all construction equipment, temporary structures, machinery, and waste materials from the quarry site.
- Clearance of debris, scrap materials, and unused aggregates.
- Stabilization of quarry slopes through grading and contouring to achieve safe slope angles.
- Loose rock fragments and unstable materials will be removed to prevent rockfall hazards.
- Construction of retaining walls, gabion walls, or rock bolting where slope instability identified.
- Development of drainage channels to safely convey surface runoff and prevent erosion.
- Installation of check dams or sediment traps where necessary to control sediment transport.
- Topsoil that was removed and stored during quarry development will be reapplied on restored surfaces to support vegetation growth.
- In areas where topsoil is insufficient, soil amendment materials may be added to improve soil fertility.
- Surface compaction will be avoided to allow proper root penetration and vegetation establishment.
- Steep quarry faces will be stabilized or fenced where necessary.
- Warning signage will be installed if deep pits or unstable areas remain.
- Access roads leading to abandoned quarry areas will be closed or controlled if no longer required.

Plantation at each site will done as suggested in "Compensatory Afforestation Plan"

13.5.23.3 Monitoring and Maintenance

- Inspection of slope stability and erosion conditions.
- Assessment of vegetation establishment and survival rates.
- Maintenance of drainage structures and erosion control measures.
- Additional planting or stabilization measures if restoration targets are not achieved.
- Monitoring will continue for a period of at least two to three years after restoration to ensure sustainable recovery of the quarry areas.

13.5.23.4 Responsibilities

- The Contractor will be responsible for implementing the quarry restoration measures.
- The Environmental Officer from DGPC will supervise and monitor the restoration activities.
- The Project Engineer and relevant authorities will review and approve the restoration works prior to site closure.

13.5.23.5 Budget

The cost of quarry restoration, including slope stabilization, revegetation, drainage works, and monitoring, will be included in the contractor's environmental management and site rehabilitation budget.

13.5.24 Muck disposal plan

The construction of project structures including coffer dams, diversion tunnels, dam complex, powerhouse, and access roads will involve huge excavation activities. A portion of the excavated material will be integrated into permanent works, while the remainder must be disposed of appropriately in designated muck disposal areas. This Muck Disposal Plan outlines the strategies, designated sites, and mitigation measures for handling the estimated 5.65 million cubic meters of muck generated during project construction.

Table 112: Description of muck disposal area

SN	Description	Area in Acres	Geographical Coordinates (approx. midpoint)	Geotechnical Setting	Stability Measures
1	MD -1	15.00	27° 7'48.69"N, 89°32'12.04"E	Moderate slope above dam, right bank	Phased lift placement, compaction, toe gabion wall, perimeter drains
2	MD- 2	40.20	27° 7'13.26"N, 89°32'3.77"E	Moderate slope on the downstream side; right bank	Toe protection, benching, sediment traps, slope monitoring
3	MD- 3	12.50	27° 7'26.70"N, 89°32'23.45"E	Lower-relief terrain, downstream left bank	Standard drainage and toe wall provisions
4	MD- 4	53.20	27° 5'34.13"N, 89°31'37.21"E	Moderate slope below highway, left bank	Engineered terracing, compaction QC, gabion toe walls, drainage diversion
5	MD-5	8.95	27° 9'19.14"N, 89°32'15.24"E	Comparatively stable terrain, upstream below highway, left bank	Standard drainage and toe wall provisions
	Total	**129.85**			

Table 113: Volume to muck generation and disposal

Project component	Total volume of muck (Mm3)	Muck to be Reused (Mm3)	Quantity of muck to be used and where to be used	Net volume to be disposed	Disposal location
Coffer Dam (U/s & D/s),	0.02	-	-	0.02	Muck Disposal- 1, Muck Disposal- 2 and Muck Disposal -4
Diversion Tunnel,	0.47	-	-	0.47	Muck Disposal- 1, Muck Disposal- 2 and Muck Disposal -4
Access tunnel	0.02	-	-	0.02	Muck Disposal- 1, Muck Disposal- 2 and Muck Disposal -4
Access roads	0.12	0.01	Road Fillings and leveling	0.11	Muck Disposal- 2 and Muck Disposal- 4
Dam Complex	4.30	-	-	4.30	Muck Disposal- 1, Muck Disposal- 2 and Muck Disposal -4
Powerhouse Complex	0.43	-	-	0.43	Muck Disposal- 2 and Muck Disposal- 4
Plunge pool & counter barrage	0.29	-	-	0.29	Muck Disposal- 2 and Muck Disposal -4
Total	5.65			5.64	

** A swell factor of 40% has been considered for calculation of muck generation from various project components.*

Table 114: Potential Impacts and Mitigation Measures

Impact Category	Potential Impacts	Mitigation Measures
Air Quality	Dust generation during loading, transportation, and dumping operations. Fugitive emissions from haul trucks and loading equipment. Dry season pollution affecting downwind communities (Chanachen, Nayakha, Lobnekha).	Water sprinkling over muck during loading to avoid dust formation. Apply water spraying on haul roads at least twice daily during dry season. Cover all transport vehicles with tarpaulins during transportation. Limit vehicle speed on unpaved haul roads to 20 km/hr. Monitor air quality at downwind community locations (Chanachen, Nayakha) weekly.

Impact Category	Potential Impacts	Mitigation Measures
Water Quality	Sediment-laden runoff from disposal sites entering water bodies. Increased turbidity in Wangchhu River and tributaries. Potential contamination of community drinking water sources (SW-07, SW-10).	Construct diversion drains to route clean water around disposal areas. Install sedimentation ponds at toe of disposal areas to capture sediment-laden runoff. Construct toe walls at downhill edges to prevent muck sliding into water bodies.
Land	Soil contamination from fuel/oil spills from haul trucks and equipment. Soil erosion from exposed dump slopes.	Store topsoil separately in designated mounds not exceeding 2m height for final reclamation. Protect stockpiles with jute netting or vegetative cover to prevent erosion. Conduct quarterly soil testing at disposal site boundaries for contamination
Noise Pollution	Noise from loading operations Traffic noise from haul trucks along transport routes. Dumping operations noise affecting nearby communities Chanachen, Bunagu, Tsimasham Village. Disturbance to wildlife in surrounding areas.	Restrict night-time haulage operations (22:00-06:00) near communities. Provide advance notification to communities of haulage schedules. Conduct weekly noise monitoring at sensitive receptors along haul routes.
Traffic and Safety	Increased heavy vehicle traffic on local roads (Chanachen farm road) and Thimphu-Phuentsholing highway. Traffic congestion and accident risks. Safety hazards to pedestrians, children, and livestock. Road damage from overloaded trucks.	Enforce speed limits (20 km/hr on unpaved roads. post limits on highways). Provide warning signs at village crossings, and schools. Schedule haulage to avoid peak pedestrian hours (school start/end times.
Slope Stability	Slope instability of disposal sites Landslide risk during monsoon season. Toe failure leading to muck sliding into water bodies or onto downstream areas.	Design disposal site slopes at safe angles (2H:1V or shallower). Dump muck in layers of 30 to 40 cm with proper compaction. Construct gabion toe walls at downhill edges before dumping.

Impact Category	Potential Impacts	Mitigation Measures
		Conduct weekly visual inspections during active dumping. monthly during inactive periods. Maintain records of any slope movement or instability.
Ecological Impacts	Habitat loss at disposal site locations. Disturbance to wildlife during dumping operations. Forest degradation where disposal sites located in forest areas. Edge effects on adjacent habitats.	Implement progressive restoration of completed disposal areas. Revegetate using native species appropriate to local ecosystem (plantation of trees as suggested in Compensatory Afforestation Plan).
Aesthetic impacts	Visual intrusion from disposal sites. Alteration of natural topography. Landscape scarring if not properly restored.	Implement progressive restoration to minimize exposed area at any time. Cover restored areas with stored topsoil and revegetate with native species (plantation of trees as suggested in Compensatory Afforestation Plan).
Muck Handling Operations	Improper collection leading to scattered muck. Inefficient loading and transport Mixing of reusable and waste material. Spillage during transport.	Load using side dump loaders in heading for efficiency.

Table 115: Monitoring Plan

Monitoring Aspect	Parameters	Location	Frequency	Responsibility
Air Quality	PM_{10}, $PM_{2.5}$, dust fall	Downwind communities (Chanachen, Nayakha, Lobnekha) disposal site	Weekly during active dumping	Environmental Officer
Water Quality	pH, turbidity, TSS, TDS	Downstream of disposal sites sedimentation pond outlets community springs (SW-07, SW-10)	Monthly	Environmental Officer
Noise Levels	Leq day, Leq night	Sensitive receptors along transport routes; nearest communities	Monthly	Environmental Officer
Slope Stability	Visual signs of movement Cracks slumping toe condition	All active and completed disposal site slopes	Weekly during active dumping monthly during inactive after heavy rainfall	Geologist Geotechnical Engineer
Erosion and Sediment Control	Gully formation; sediment pond effectiveness drainage function	Disposal site slopes sedimentation ponds drainage channels	Weekly during active dumping after major storms	Environmental Officer
Dumping Operations	Volume dumped Layering Compaction boundary adherence	Active disposal areas	Daily	Contractor

Monitoring Aspect	Parameters	Location	Frequency	Responsibility
Haul Road Conditions	Road surface condition dust generation spillage	All haul routes (Chanachen farm road)	Weekly	Contractor
Vehicle Compliance	Covering of loads speed limits maintenance condition	Haul routes disposal site entry	Daily inspections random checks	OHS Officer
Soil Contamination	pH, heavy metals	Disposal site boundaries fuel storage areas	Quarterly	Environmental Officer
Community Complaints	Dust, noise, traffic, vibration complaints	Affected villages (Chanachen, Nayakha, Bunakha, Lobnekha)	As received	CLO
Rehabilitation Progress	Vegetation survival erosion control slope stability	Completed disposal site areas	Quarterly for first 3 years	Environmental Officer

13.5.24.1 Long-term Monitoring

- Monitor vegetation establishment and survival rates
- Inspect slope stability and drainage system performance
- Conduct maintenance including replanting and drain clearance as required

13.5.24.2 Responsibilities

Table 116: Responsibilities

Responsibility	Agency
Implementation of muck disposal operations	Contractor
Monitoring compliance with environmental norms	Project Management Consultant (PMC)
Overall supervision and approval	BHPL
Long-term monitoring of restored sites	BHPL (post-construction)

13.5.24.3 Budget

All costs associated with muck disposal, including site preparation, environmental management measures, and final restoration, shall be included in the contractor's scope of work and reflected in the contract documents.

13.5.25 Cultural heritage management plan (CHMP)

This CHMP encompasses all Project-related activities associated with the management of findings which are identified as culturally important items. The requirements of this Plan are to be followed by Contractors and subcontractors within the project construction site as necessary for construction of hydropower infrastructure.

The Plan is applicable to all known, as well as not yet identified, culturally important items that may be impacted, either directly or indirectly, by the Project activities. The Plan will be implemented during all phases of the Project including pre-construction, construction, operation, and decommissioning. The focus of this Plan is on impacts that can take place through the construction of physical infrastructure and associated facilities of the hydropower project.

The Plan has been established to minimize impact to the areas' culturally important items from Project activities. Potential risks and mitigation measures were compiled through the risk assessment process combined with experiences gained from recent hydropower projects in Bhutan, including community consultations conducted in July 2025.

13.5.25.1 Objectives

The objectives of the Cultural Heritage Management Plan are to:

- Avoid potential impact on cultural and religious sites (including both archaeological sites and historical /traditional important sites) where necessary and practicable
- Where avoidance is not possible, manage cultural sites in compliance with the requirements of Bhutanese laws and regulations and in consultation with relevant Bhutanese Government officials and local stakeholders.

- Provide guidance compliant with the ADB SPS 2009 recommendations on how impact on cultural heritage documented and managed;
- Establish ADB SPS 2009 aligned Chance Finds Procedure (CFP) to minimize impacts to not yet identified cultural resources that may be identified/discovered by Project personnel during the course of the execution of Project activities;
- Enhance relationships with affected communities and eliminate community grievances related to impacts to cultural items;
- Minimize Project delays by promoting compliance with national regulations and other Project requirements; and,
- Define the roles and responsibilities for implementing the Plan.

13.5.25.2 Cultural and religious sites in project area

The Project's AoI is embedded within a culturally significant landscape, encompassing over 30 religious and culturally important sites. For assessment purposes, these sites are categorized by their proximity to construction zones and the level of potential impact. Those closest to major construction areas—such as the dam, quarry, batching plants, and transport corridors—are considered high-risk due to their exposure to noise, vibration, dust, and visual disruption. In contrast, sites located in the remote upstream sections of the AoI are shielded by distance and terrain, making them less vulnerable to direct impacts. While these sites are acknowledged as part of the broader cultural context, they are not prioritized for immediate mitigation.

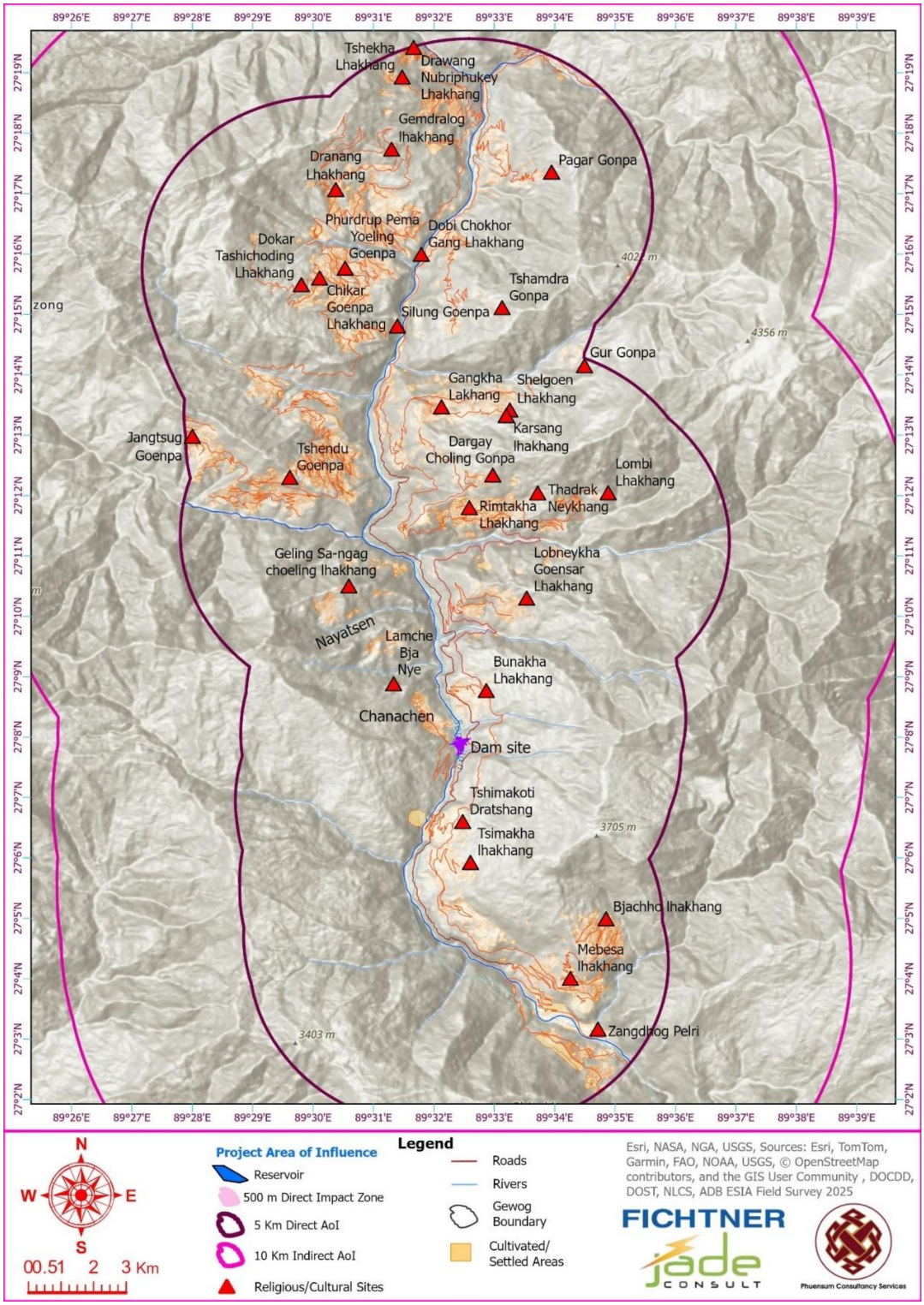


Figure 82: Religious and cultural heritage sites in the Bunakha HPP's AoI

Table 117: Cultural and religious sites and Neys in the two Gewogs

Sl. No.	Name of Heritage Sites	Gewog
1	Pagar Goenpa	**Chapcha**
2	Lombee lhakhang	
3	Rimtekha Lhakhang	
4	Gangkha lhakhang	
5	Thardrak Goenpa	

Sl. No.	Name of Heritage Sites	Gewog
6	Shelma Goenpa Ney Lhakhang	
7	Kudung Chorten Lhakhang	
8	Shelgoen Wogma Lhakhang	
9	**Bunakha Lhakhang**	
10	Dokhachu Goenpa/ Dorgoen Dargay Chholing	
11	Tshamdrak Goenpa	
12	Tshamdrak Goenpa neykhang	
13	Gurgoen Lhakhang	
14	Lo Nyelkha Lhakhang	
15	Lobneykha Goensar Lhakhang	
15	Chapcha Dzong	
16	Boey goenpam lungrig goenpa	
17	Karsel Lhakhang	
Other important neys withing Chapcha gewog		
1	Zhanbdrung thri (Boulder)	**Chapcha**
2	Patshelling Trulku home	
3	Dorji pham ney	
4	Ney go	
Name of Heritage Sites		
1	Kamji Kuenga Chhoeling Lhakhang	**Geling**
2	**Gerling Sanga Choling lhakhang/Geling Goenpa**	
3	Dapa Mangi Burgoenpa Lhakhang	

13.5.25.3 Socio-economic and Cultural Context

Social dimension of cultural Sites

The cultural sites within the Project Area are not merely physical structures but represent living cultural institutions that:

- Serve as centers for community gathering and spiritual practice
- Preserve ancient religious scriptures, including sacred texts
- Maintain the lineage of Buddhist teachings and traditions
- Offer spaces for social interaction during festivals and ceremonies
- Are repositories of collective memory and cultural knowledge

Economic Dimensions

The cultural sites contribute to local economies through:

- Religious tourism and pilgrimage
- Donations and offerings that support monks and site maintenance
- Associated crafts and ritual object production

13.5.25.4 Public consultation

During the public consultation held in Chanachen and Bunakha in July 2025 and April 2025, community members raised concerns regarding direct impact on cultural sites.

Issues raised during consultation and data based on survey is summarized table below:

Table 118: Major Issues raised during public consultation and physical survey assessment

Issue raised	Site	Community Perspective
Blasting impacts	Lamche Bja (Elephant Cliff)	Potential impact due to blasting
Cliff stability	Lamche Bja	Geotechnical concerns about the stability of the cliff face
Noise pollution	Sites near construction	Anticipated noise disturbance during construction phase.

13.5.25.5 Consultation with religious leaders

The Lams (spiritual leaders) of Bunakha Lhakhang and Geling Goenpa participated in public consultations. They expressed concerns primarily related to noise pollution anticipated during construction.

- Establishment of a Spiritual Foundation: Encompassing the two religious' sites (Bunakha Lhakhang and Geling Goenpa)
- Recognition as Spiritual Guardians: They suggested that Bunakha Lhakhang and Geling Goenpa be recognized as spiritual guardians of the project, with their protective presence invoked:

  - From the groundbreaking ceremony
  - Throughout the construction phase
  - Through commissioning and beyond
  - For the entire operational life of the project

13.5.25.6 Summary of the potential Impacts

The following locations are identified as particularly vulnerable and require focused and pay more attention for protection and management:

- Bunakha Lhakhang:

A temple situated on the eastern riverbank, directly adjacent to the main access road. Its visibility from the proposed quarry and proximity to traffic routes make it susceptible to construction-related noise, vibration, and dust.

- Lamche Bja (Elephant Cliff):

A spiritually revered cliff located upslope from the proposed quarry. During the public consultation held in Chanachen in July 2025, community members identified this as a critical issue. They expressed fear that blasting could disturb protective deities, raising a primary spiritual and cultural concern and the stability of the cliff face.

- Lobnekha Heritage Village:

Positioned 8-10 km north-northeast of the main activity zone, this settlement lies directly downwind. Prevailing wind patterns increase its exposure to airborne pollutants, including dust and combustion emissions.

- Nayatsen and Tsho Sacred Sites & Geling Goenpa:

Located northwest of the Project site, these sites and the active monastery share a downwind position. Baseline data indicates poor air dispersion and a quiet soundscape, making them sensitive to dust and low-frequency noise from blasting operations.

13.5.25.7 Sites with Low to Negligible Risk

Remained other cultural sites within the AoI are considered low-risk/or negligible due to their distance from construction activities. These sites are located several kilometers upstream of the Bunakha HPP dam axis and consist of a cluster of temples and monasteries - such as Tshekha Lhakhang, Drawang Nubriphukey Lhakhang, Pagar Gonpa, and Dobi Chokhor Gang Lhakhang.

13.5.25.8 Potential direct impact

Based on detailed assessment of project layout and site locations, none of the cultural heritage sites are expected to experience direct physical impact (such as land acquisition, demolition, or physical encroachment) during the construction phase. The project facilities have been sited to avoid direct disturbance to all known cultural and religious sites.

13.5.25.9 Potential Indirect Impacts

Despite the absence of direct impacts, the following indirect impacts have been identified for sites in proximity to construction activities:

Table 119: Potential Impacts

Potential impact area	Description	Affected Sites
Noise	Construction machinery, blasting, traffic	Bunakha Lhakhang, Lamche Bja, sites near construction
Vibration	Blasting operations, heavy equipment	Lamche Bja, Bunakha Lhakhang
Dust/Air Pollution	Construction dust, vehicle emissions, blasting	Downwind sites (Lobnekha, Nayatsen, Geling Goenpa)
Visual Intrusion	Quarry visibility, construction activities	Bunakha Lhakhang, Lamche Bja
Social Disruption	Influx of workers, cultural changes	All communities with cultural sites
Access Impacts	Temporary restrictions during construction	Sites near construction zones

13.5.25.10 Mitigation Measures

General Mitigation Approach

The mitigation strategy follows the hierarchy of:

- Avoidance - Prioritize avoiding impacts to cultural sites
- Minimization - Where avoidance is not possible, minimize impacts

- Mitigation - Implement measures to reduce residual impacts
- Compensation/Enhancement - Where appropriate, enhance cultural heritage

Site-Specific Mitigation Measures

Table 120: Site specific mitigation measures

Site	Mitigation Measures	Responsibility	Timing
Bunakha Lhakhang	Establish buffer zone around Lhakhang.	Contractor, ESHS	Pre-construction, Continuous
	Install vibration monitoring equipment.		
	Implement dust suppression measures.		
	Restrict night-time construction near site.		
	Conduct pre-construction condition survey.		
	Maintain community liaison for feedback.		
Lamche Bja (Elephant Cliff)	Conduct detailed geotechnical assessment of cliff stability.	Contractor, ESHS	Pre-construction, During blasting
	Implement controlled blasting with reduced charges.		
	Monitor vibration levels during blasting.		
	Consult with community on blast timing (avoid auspicious days).		
	Perform spiritual ceremonies before blasting (consult Lam).		
	Install protective barriers if needed.		
Lobnekha Heritage Village	Implement dust suppression on access roads.	Contractor, ESHS	Construction phase
	Monitor air quality in village.		
	Provide advance notice of high-dust activities.		
	Consider vegetative barriers if effective.		
	Maintain community grievance mechanism.		
Nayatsen and Tsho Sacred Sites	Monitor noise levels at site boundaries.	Contractor, ESHS	Construction phase
	Implement low-noise blasting techniques.		
	Schedule blasting to minimize disruption.		
	Maintain communication with site caretakers.		
Geling Goenpa	Establish communication protocol with monastery.	Contractor, ESHS	Pre-construction, Continuous
	Consult on timing of sensitive religious periods.		
	Consider spiritual recognition as proposed by Lams.		

13.5.25.11 Spiritual and Community Engagement Measures

In response to the proposal from Lams of Bunakha Lhakhang and Geling Goenpa, the Project will:

- Formally recognize Bunakha Lhakhang and Geling Goenpa as spiritual guardians of the project

Invoke protective presence through ceremonies at:

- Groundbreaking ceremony
- Key construction milestones
- Project commissioning

Establish a Spiritual Foundation encompassing the two religious' sites, with:

- Regular communication between project management and Lams
- Support for annual rituals and prayers for project safety
- Conduct pre-construction blessings at major cultural sites near construction activities

13.5.25.12 Enhancement Measures

The Project will consider enhancement measures for cultural heritage:

Table 121: Enhancement measures

Enhancement	Description	Potential Sites
Site Improvements	Support for maintenance and preservation of cultural sites	Bunakha Lhakhang, Geling Goenpa
Documentation	Support for documenting intangible cultural heritage	All communities
Access Improvements	Safe access to cultural sites during/after construction	Affected sites
Information Materials	Cultural heritage information for workers and visitors	Project area

13.5.25.13 Responsibility

BHPL Responsibility

BHPL and BHPP shall have the following responsibilities for CHM:

Table 122: BHPL Responsibility

Responsibility	Description
Overall Compliance	Ensure overall compliance with this CHMP, Bhutan's national regulation, and ADB SPS 2009 requirements. Coordinate with Department of Culture
Approval	Review and approve Contractor's Cultural Heritage Management procedures
Community Relations	Maintain high-level relationship with religious leaders and community representatives
Spiritual Recognition	Formalize recognition of spiritual guardianship as proposed by Lams
Monitoring Oversight	Oversee implementation of monitoring programs for cultural sites
Grievance Review	Review and address escalated grievances related to cultural heritage
Reporting	Include cultural heritage monitoring results in regular project reports to ADB and Government
Enhancement Programs	Implement cultural heritage enhancement programs

Contractor Responsibility

The Contractor(s) shall have the following responsibilities for cultural heritage management:

Table 123: Contractor Responsibility

Responsibility	Description
CESHMP Implementation	Implement all site-specific mitigation measures identified in this CHMP
Worker Training	Ensure all workers receive training on cultural heritage protection and Chance Find Procedure
Buffer Zones	Establish and maintain buffer zones around cultural sites as directed
Monitoring	Conduct required monitoring (vibration, noise, dust) at cultural sites
Reporting	Report any incidents affecting cultural sites immediately to BHPL-ESHS
Chance Finds	Implement Chance Find Procedure if cultural materials are discovered
Community Liaison	Cooperate with community leader for community engagement related to cultural sites
Compliance	Ensure subcontractors comply with all cultural heritage requirements

Contractor Minimum Requirements:

The Contractor's CESMP shall include:

- Cultural heritage risk assessment for all construction activities
- Blasting management protocol for areas near Lamche Bja and Bunakha Lhakhang
- Dust and noise management measures for downwind cultural sites
- Worker training program on cultural heritage
- Monitoring plan for vibration, noise, and air quality at sensitive receptors
- Reporting protocol for cultural heritage incidents
- Chance Find Procedure implementation plan

13.5.25.14 Monitoring

Table 124: Cultural Heritage Management Plan - Monitoring Program

Monitoring Aspect	Parameters / Issues to Monitor	Monitoring Method	Responsibility	Frequency / Timing	Indicators / Thresholds	Corrective Action if Exceeded
Physical Condition of Cultural Sites	Structural integrity; visible damage; cracks; deterioration	Visual inspection; photographic documentation; condition assessment	ESHS, Religious Leaders	Quarterly; pre-construction baseline; post-construction	No new damage, cracks, or deterioration beyond baseline	Engage structural engineer; implement repairs; review nearby activities; consult religious leaders
Vibration Impacts	Ground vibration from blasting, construction equipment, heavy vehicles	Vibration monitors at sensitive sites (temples, monasteries, sacred cliffs)	Contractor	Continuous during blasting; weekly during active construction near sites	Cracks	Halt blasting/construction; review blast design; conduct engineering assessment; inform DGPC and community
Noise Levels	Ambient noise; construction noise; blasting noise; low-frequency noise	Noise meters at cultural site boundaries	Contractor,	Monthly; during blasting events; during high-noise activities	Bhutan National Standard	Adjust construction methods; install noise barriers; reschedule activities; provide advance notice to communities
Air Quality / Dust	PM_{10}, $PM_{2.5}$, dust deposition; visual dust	Air quality monitors; visual observation	Contractor,	Monthly; increased frequency during dry season; during earthworks	Bhutan National Standard	Increase water spraying; reduce exposed areas; cover stockpiles; temporarily suspend activities during adverse conditions
Blasting Management	Blast timing; Community notification;	Review blast logs; vibration monitoring; consultation records	Contractor	Before each blast; during each blast; after each blast	No blasting during night-time (7 PM - 7 AM); no blasting on auspicious religious days; vibration within limits; community notified 48 hours in advance	Reschedule blasting; revise blast design; conduct spiritual ceremonies; Enhance community communication
Buffer Zone Compliance	Encroachment around cultural sites	Site inspection; GPS verification; photographic records	Contractor	Weekly during construction near cultural sites	No construction activities, stockpiling, or vehicle parking within designated buffer zones	Immediate removal of encroachment; worker retraining; contractor penalties for repeated violations
Worker Behaviour	Respectful conduct; unauthorized access; adherence to Code of Conduct	Site supervision; worker monitoring; community feedback	Contractor,	Daily; continuous	No reports of disrespectful behaviour; no unauthorized entry to sacred sites	Worker disciplinary action (warning, suspension, termination); additional cultural sensitivity training
Community and Religious Leader Engagement	Consultation frequency; feedback received; relationship quality	Meeting minutes; consultation records; satisfaction surveys	DGPC, Contractor	Monthly during construction; Semi-annual during operation	Regular consultations conducted; concerns documented and addressed; positive relationship maintained	Increase engagement frequency; address concerns promptly; involve senior management if relationship deteriorates
Grievance Redress	Cultural heritage-related grievances; resolution timeliness	Grievance log review; tracking system	DGPC, Contractor	Monthly	All grievances acknowledged and resolved; no repeat grievances	Expedite resolution; escalate to project management; involve third-party mediation if needed
Worker Training Compliance	Training completion; knowledge retention	Training records; pre-employment orientation; refresher training logs	ESHS, Contractor	Monthly during mobilization; quarterly during construction	100% of workers trained on CHMP, Chance Find Procedure, and Code of Conduct before site access	Suspend non-compliant workers from site; conduct make-up training; impose contractor penalties for systemic non-compliance
Chance Find Procedure Implementation	Discovery of unknown cultural materials; adherence to CFP protocol	Incident log; discovery reports; authority notifications	All personnel, Contractor, ESHS	Continuous; immediate reporting when discovery occurs	Any chance finds properly documented, reported, and managed per CFP; work halted in discovery area	Implement CFP steps immediately;
Cultural Heritage Enhancement	Implementation of enhancement commitments (spiritual foundation, festival support, site improvements)	Progress tracking; financial records; community feedback	ESHS, Contractor	Annually; per commitment schedule	Enhancement activities implemented as planned; community satisfaction with initiatives	Adjust implementation timeline; report to ADB; enhance communication on progress
Documentation and Reporting	Monitoring records; photographic documentation; compliance reports	Record review; report submission tracking	ESHS, Contractor	Monthly; quarterly; annually	All monitoring data recorded; reports submitted on time; photographic records maintained	Improve record-keeping systems; assign additional staff; escalate reporting deficiencies to management

Monitoring Aspect	Parameters / Issues to Monitor	Monitoring Method	Respon sibility	Frequency / Timing	Indicators / Thresholds	Corrective Action if Exceeded
Regulatory Compliance	Compliance with national regulation; ADB SPS 2009 requirements	Compliance audits; regulatory inspections	ESHS, E	Annually; during regulatory inspections	No non-compliance findings; all regulatory approvals obtained	Address findings immediately; develop corrective action plan; report to authorities and ADB

Community-Based Monitoring

- Religious leaders will be invited to participate in visual inspections of cultural sites
- Community representatives may accompany monitoring teams
- Feedback sessions will be held with Lams and community members quarterly
- Photographic documentation will be maintained for all cultural sites

13.5.25.15 Reporting

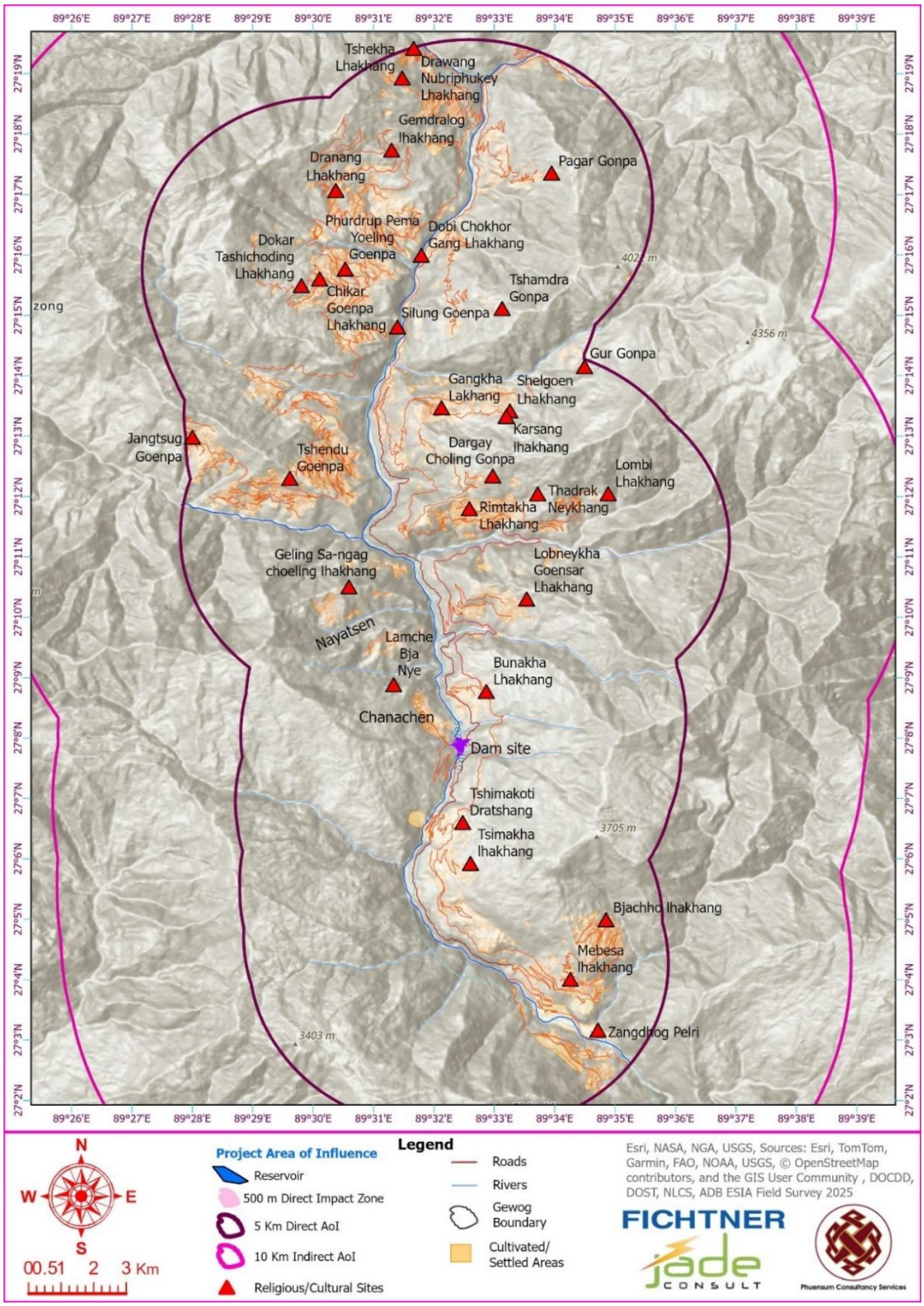
Monitoring results shall be included in:

- Monthly project progress reports
- Quarterly environmental monitoring reports
- Annual reports to ADB and government agencies
- Grievance closure reports (if applicable)

13.5.25.16 Chance Find Procedure

Discovery
↓
Stop Work Immediately
↓
Secure Area (barriers, restrict access)
↓
Notify Site Supervisor
↓
Contractor E&S Officer Assess and Notifies BHPL (Within 24 hrs)
↓
BHPL notifies Dzongkhag Cultural Officer/ Department of Culture
(Within 48 hrs)
↓
Expert Assessment (within 7 days)
↓
Authority Determination
↓
Implement Protection/Rescue
↓
Work Resumes (with written permission)

Appendix A: Maps of Cultural Heritage Sites



13.5.26 E-flow Management plan

A separate E-flow Report with E-flow management plan has been prepared. Kindly refer to the E-flow Management Plan for details.

13.5.27 Climate risk management plan

Refer Section 9.4 of Chapter 9 Climate Impact Assessment

13.5.28 Cumulative impacts management plan

Based on the impact assessment, various sub-management plans have been prepared. Therefore,
implementation of the above-mentioned sub-management plans and Biodiversity Action Plan is considered sufficient for the management of cumulative impacts.

14 Environmental and Social Monitoring Programme

The Environmental and Social Monitoring Program (ESMoP) for the Bunakha HPP includes:

- Definition and detailing of required monitoring actions
- The frequency, timing and location for the monitoring actions
- Associated responsibilities.

14.1 Self-Monitoring and External Auditing

Generally self-monitoring is a basic requirement to show the compliance of development projects with the standards as outlined in the ESMP and represents a suitable basis for the successful realization of the required auditing procedures. In addition, internal inspections are an appropriate method of conservation of evidence in case of an incident, accident or emergency situation.

All data from the internal inspection program during pre-construction, construction, and decommissioning as requested by the ESMP shall be reported by the Contractors to ESHS. Summarized data shall be submitted quarterly to BHPL, who shall then forward the information to the responsible authorities (DECC) for assessment and follow up in accordance to national law and the Environmental Approval's conditions.

Table 125: Suggestion of an internal inspection plan for the Bunakha HPP

Phase	Inspection Party	Inspections Schedule
Pre-construction, Construction, and Decommissioning	Contractor's ESHS Manager	Quarterly ESHS site inspections and reporting to ESHS
		Site inspection upon occurrence of an ESHS accident, incident or emergency and reporting to ESHS
		Site inspection upon receiving of a worker's or community's grievance and reporting to ESHS
	Contractor's ESHS Supervisor	Weekly ESHS site inspections and reporting to the ESHS Manager
		Site inspection upon occurrence of an ESHS accident, incident or emergency
		Site inspection upon receiving of a worker's or community's grievance
Operation	ESHS	Bi-annual ESHS site inspections and reporting to the DECC
		Site inspection upon occurrence of an ESHS accident, incident or emergency
		Site inspection upon receiving of a worker's or community's grievance

Besides the internal inspections, external auditing of the implementation of the mitigation and monitoring measures defined for the Bunakha HPP is recommended. The BHPL or an Independent ESHS Consultant acting on their behalf shall continuously supervise the Project sites during the pre-construction, construction, decommissioning, and operational phases. In case deviations from the Project's ESMP are identified, ESHS shall request the Contractor to timely define and apply measures to rectify the deviation and related consequences, as applicable. The following auditing plan is suggested.

Table 126: Suggestion of an external auditing plan for the BHPP

Phase	Duration	Auditing Party	Audits Schedule
Pre-construction	1 year	ESHS or Independent ESHS Consultant If resources are available, DECC shall consider joining the audits on a regular basis	First audit at start of the pre-construction stage and then every 3 months
Construction	5 years		First audit at start of the construction stage and then every 3 months
Operation	At least 25 years *		First audit at start of the operation; one audit per year in the first 5 years; one audit every 5 years until decommissioning
Decommissioning	Assumed up to 6 years including planning, reservoir drawdown, infrastructure removal and landscape restoration		First audit at start of the decommissioning stage and then every 3 months
All phases	-		Upon occurrence of an ESHS accident, incident or emergency

* The technical lifetime of the Bunakha HPP is of 100 years (DPR, 2026)

14.2 Adaptive Management

The monitoring of the works may reveal the need to adapt the measures of the Contractors' ESMPs to specific site conditions not known at the time of preparation of those documents or the ESIA. Items which are not anticipated in this ESMP of the Contractors' ESMPs may come up, as well as areas that need improvements. The Contractors shall be ready to handle both cases by adapting the dispositions of the respective ESMPs as necessary.

Updates may be also needed to ensure compliance with all permits' requirements. This includes also the permits issued after approval of the ESMPs by ESHS.

Any changes to the commitments of the ESIA and the Project's ESMP shall not be undertaken without the previous approval of ESHS. The changes must not enhance the negative impacts expected from the Project, reduce the efficiency of the mitigation measures, or propose monitoring exercises which are less strict than those stated within the Project's ESMP.

As part of the adaptive management framework, BHPL shall periodically review advances in Earth Observation, AI-assisted monitoring, and digital technology and assess their applicability to the BHPP's monitoring programme.

14.3 Compilation of the ESMoP for the Bunakha HPP

The ESMoP predicts two types of monitoring actions:

- Compliance monitoring: monitoring actions to verify if the mitigation measures are implemented, which include: visual inspections of the works, review of reports/plans, and reporting.
- Effects monitoring: monitoring actions to verify if the mitigation measures have the desired result, which include: sampling and analysis of environmental parameters, and visual inspection of environmental factors (e.g., inspecting fences for signs of vandalism).

14.3.1 Compliance monitoring

Compliance monitoring shall be done at all sites during all phases as detailed in Table 127.

Table 127: Environmental and Social Monitoring Programme for the Bunakha HPP - compliance monitoring

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
Physical Environment				
Pre-Construction	Air Emissions	Verify emissions testing of all machinery every 6 month. Ensure trucks transporting materials are covered with tarpaulins. Maintain continuous air quality monitoring at ANSP-2, ANSP-4.	Contractor / Environmental Officer	Every 6 months for emissions. Daily for covered trucks. Continuous for air monitoring
	Noise Pollution	Confirm heavy haulage restricted to daytime (06:00-22:00) Ensure crushing/batching prohibited at night (22:00-06:00). Maintain continuous noise monitoring at ANSP-2, ANSP-4. Enforce speed limit (20 km/h) in villages		Daily for daytime restriction. Daily for night-time prohibition. Continuous for noise monitoring. Daily for speed limit
	Degradation of water quality	Maintain 50m buffer zones around		Weekly for buffer zones. After each clearing event. Daily for batching plants.

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		springs (SW-05,07,09,10). Install erosion controls immediately after clearing. Ensure concrete wash-water passes pH neutralization. Verify bund walls (110% capacity) at fuel depots. Check camp septic systems 50m from watercourses. Operate real-time monitoring at SW-01, SW-02		Continuous for water monitoring.
	Degradation of Soil Quality/land pollution	Implement topsoil stripping (300mm) and stockpiling. Verify bunded areas on impervious flooring.		Before clearing for topsoil.
Construction	Air Emissions	Cover haul trucks to MD-2, MD-4 with tarpaulins. Verify emissions testing every 6 months. Restrict blasting to daytime. notify leaders 24-48hrs ahead. Use Wangchhu River water for dust suppression. Maintain air monitoring at	Contractor / Environmental Officer	Daily for covered trucks. Daily for wheel washing. Every 6 months for emissions. Per blast for notification. Daily (dry season) for water. Continuous for monitoring

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		ANSP-1, ANSP-2,, ANSP-3, ANSP-4 , ANSP-5 ANSP-6, ANSP-7, and ANSP-8, and ANSP-9)		
	Noise Pollution	Operate siren warning system before blasting. Install vibration monitors at Bunakha Lhakhang, Lamche Bja, Chanachen. Restrict haulage to daytime (06:00-22:00). Complete dilapidation survey of Chanachen, Bunakha structures. Record vibration data for each blast	Contractor / Environmental Officer	Per blast for siren. Continuous for vibration. Daily for daytime restriction. Once pre-construction. Per blast for records.
	Water Pollution	Deploy turbidity curtains in diversion channels. Maintain minimum environmental flow. Install sedimentation basins with oil/water separators. Ensure concrete wash-water pH neutralized. Construct sedimentation ponds at MD-1, MD-2, MD-4.	Contractor / Environmental Officer	Daily during river works. Continuous for flow.. Daily for tunnel works. Daily for concrete wash. Before dumping at sites. Continuous for monitoring.

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		Operate real-time monitoring at SW-01, SW-02		
	Degradation of Soil Quality/land pollution	Provide secondary containment for fuel tanks. Inspect slope stability at disposal sites after heavy rain. Sample water quality at SW-2 monthly. Implement progressive rehabilitation with native species	Contractor / Environmental Officer	Weekly for containment. After each heavy rain. Monthly for SW-2. Quarterly for rehabilitation
	Impacts on Land and Geology	Conduct geotechnical inspections of slopes near blast zones. Implement stabilization measures if instability detected. Regular inspection of cut slopes, spoil disposal sites, quarry/borrow areas, sediment control structures like in nala of left bank, and temporary facilities to ensure implementation of erosion control, slope protection, and approved disposal/restoration measures	Contractor / Geotechnical Specialist	Continuous during construction. Immediately upon detection. Per blast for vibration.
	Changes in River Morphology	Deploy sediment barriers in diversion channels.	Contractor / Environmental Officer	Daily during river works.

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		Sequence plunge pool and counter barrage works to minimize concurrent sediment generation.		
Operation	Noise Quality	Provide ear plugs to workers in high-noise areas. Schedule maintenance during daytime; notify communities. Conduct annual worker health checkups.Install acoustic insulation/silencers as needed	BHPL ESHS	Daily for PPE availability. Per maintenance event. Annually for health checks. As needed.
	Water Quality	Store hazardous materials in bunded areas (110% capacity). Pass powerhouse drainage through oil-water separators. Inspect critical equipment monthly. Monitor downstream water quality quarterly at SW-1, SW-2 .	BHPL ESHS	Weekly for storage inspection. Daily for separators. Monthly for equipment. Quarterly for monitoring.
	Impacts on Land and Geology	Limit reservoir drawdown/refilling to 2.5 m/day. Implement Reservoir Operation Manual. Conduct bathymetric surveys every 5 years.	BHPL ESHS	Continuous for rate. Annually for manual review. Every 5 years for surveys.

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		Periodic geotechnical inspection of slopes and riverbanks; monitoring of nala flow condition, erosion, sediment deposition, and drainage functionality near project structures		
	Changes in River Morphology	Maintain environmental flow as per E-flow Plan. Coordinate real-time with Chhukha HPP and Tala HPP .	BHPL ESHS	Continuous for flow. Daily for cascade coordination
Decommissioning	Air Emissions	Water spray on demolition areas and haul roads. Provide safety masks to workers. Conduct safety training before decommissioning.	BHPL ESHS	Daily during demolition. Before demolition.
	Impacts on Land and Geology	Limit reservoir drawdown to 2.5 m/hr. Install early warning systems for downstream communities. Implement erosion controls (trenches, check dams, terracing). Conduct sediment flushing during high flow. Coordinate with Chhukha Dam operators	DGPC	Continuous for drawdown. Before drawdown.Before monsoon season. During high flow. Throughout decommissioning.

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
Biological Environment				
Pre-Construction	Unnecessary vegetation clearance	Confirm boundary demarcation in field before clearing; verify cleared area matches approved footprint (m²/ha)	Contractor	Prior to site clearance
	Loss of flora of conservation significance	Verify flora survey conducted and rescue/relocation records maintained (species list, number of individuals, relocation sites)	Contractor with DoFPS / NBC	Pre-construction
	Lack of biodiversity rescue planning	Review and approve flora, fauna, and fish rescue protocols and ensure availability of trained personnel	BHPL ESHS / Supervision Consultant	Pre-construction
	Disturbance to wildlife habitats	Verify inclusion of wildlife protection clauses in contract documents	Supervision Consultant	Pre-construction
	Improper muck disposal planning	Verify approved muck disposal sites and clearances, including buffer distance from water bodies	Contractor / Engineer	Pre-construction
	Permanent loss of forest land	Verify compensatory afforestation plan approved by DoFPS including plantation targets (area in ha, number of saplings)	BHPL ESHS	Pre-construction
	Lack of restoration planning	Confirm identification of greenbelt and restoration areas	Contractor / Supervision Consultant	Pre-construction
Construction	Loss of vegetation and forest cover	Measure cleared area (ha) against approved footprint and verify no excess clearing	Contractor	Weekly during clearing

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
	Loss of flora species	Verify flora rescue records (species, number relocated) and survival rate (%) at relocation sites	Contractor with DoFPS	Prior to and during clearing
	Disturbance to mammals	Check worker compliance (no hunting), awareness records, and wildlife sightings/incidents (number/month)	Contractor	Monthly
	Wildlife injury or displacement	Verify wildlife rescue records (number of individuals rescued, treated, and released)	Contractor/ BHPL ESHS	As required
	Increased poaching risk	Verify awareness training conducted (number of sessions/workers trained) and coordination with DoFPS patrols	Contractor	Monthly
	Human–wildlife conflict	Verify grievance records and monitor number of conflict incidents and mitigation actions	BHPL ESHS / Supervision Consultant	Quarterly
	Disturbance to bird nesting habitats	Check clearing schedule against breeding season restrictions and record any disturbance incidents	Contractor / BHPL ESHS	Seasonal
	Habitat fragmentation	Field verification of ecological corridor retention (width and continuity maintained)	Contractor	Monthly
	Sedimentation affecting aquatic biodiversity	Monitor turbidity (NTU) upstream and downstream and inspect sediment control structures	Contractor / BHPL ESHS	Monthly and during earthworks

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
	Fish mortality during dewatering	Verify fish rescue records (species, number relocated, survival rate %)	Contractor / BHPL ESHS / DoFPS	During cofferdam / dewatering
	Disturbance to fish habitat	Inspect riparian buffer zones (width maintained) and confirm no muck disposal in watercourses	Contractor	Monthly
	Invasive fish species introduction	Verify no stocking of non-native species and monitor aquatic species composition	Contractor	Quarterly
	Habitat degradation due to muck disposal	Inspect muck disposal sites and slope stabilization (% area stabilized)	Contractor	Monthly
	Loss of riparian vegetation	Verify restoration of riverbanks using native species and assess vegetation cover (%)	Contractor	Post-construction / periodic
	Spread of invasive plant species	Conduct vegetation surveys, measure invasive species coverage (%), and verify removal effectiveness	Contractor	Quarterly
	Land degradation and slope instability	Inspect greenbelt development (area planted, survival rate %) and slope stabilization effectiveness	Contractor	Monthly
	Loss of vegetation due to temporary works	Verify restoration completion and vegetation establishment (survival rate %)	Contractor	Post-construction
Operation	Reduced downstream aquatic habitat	Monitor environmental flow (m^3/s) against approved flow regime and seasonal requirements	BHPL ESHS	Continuous

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
	Changes in fish population	Conduct fish monitoring using CPUE, species diversity indices, and seasonal abundance assessments	BHPL ESHS	Biannual
	Fish migration disruption	Monitor fish movement and migration patterns and identify potential barriers	BHPL ESHS	Annual
	Degradation of riparian vegetation	Inspect riparian vegetation condition (cover %, species composition)	BHPL ESHS	Annual
	Disturbance to wildlife habitats	Conduct wildlife monitoring using camera traps (detections), transect surveys, and sightings	BHPL ESHS	Annual
	Human–wildlife conflict	Review conflict incidents (number/year) and mitigation effectiveness	BHPL ESHS	Quarterly
	Loss of habitat connectivity	Verify maintenance of ecological corridors and habitat continuity	BHPL ESHS	Quarterly
	Spread of invasive species	Conduct surveys to assess invasive species coverage (%) and control effectiveness	BHPL ESHS	Annual
	Poor survival of plantation	Monitor plantation survival rate (%) and replanting records	BHPL ESHS	Annual
Decommissioning	Vegetation disturbance	Verify extent of clearing (ha) is limited to required footprint	BHPL ESHS	During decommissioning
	Disturbance to wildlife habitats	Monitor activities in sensitive areas and record wildlife	BHPL ESHS	During decommissioning

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		disturbance incidents		
	Sediment release	Monitor turbidity (NTU) and inspect sediment control measures	BHPL ESHS	During dismantling
	Habitat degradation	Verify restoration works and vegetation establishment (cover %, survival rate %)	BHPL ESHS / Contractor	Post-decommissioning
	Disturbance to riparian vegetation	Inspect riparian restoration and assess vegetation recovery (cover %, stability)	BHPL ESHS / Contractor	Post-decommissioning
	Loss of ecological stability	Monitor long-term restoration success (vegetation cover %, species diversity)	BHPL ESHS / Contractor	Post-decommissioning (periodic)
Human Environment				
Pre-Construction	Land acquisition compensation and livelihood restoration	Verify implementation of Resettlement Plan (RP) including compensation disbursement, land substitution registration, and livelihood restoration activities	BHPL ESHS	Quarterly at Geling and Chapcha Gewogs, affected households (30 HH)
		Verify compensation at full replacement cost for structures, fruit-bearing trees, and immovable assets without depreciation	BHPL ESHS / Contractor	Prior to land possession affected households
	Worker safety during site preparation and construction	Implementation of Occupational Health and Safety Plan and Labor Management Plan	Contractor	Monthly/construction sites, worker camps
		Worker induction training completion and Code of		Prior to site access/all work sites

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		Conduct signed by all workers		
		Worker GRM established and functional		Before operations/all work sites
	Community safety near project construction activities	24-48 hours advance notification to local communities before construction activities	Contractor / CLO	Before each activity/Chanachen, Bunakha, Tshimalakha
		Blasting Operation Plan compliance	Contractor	Each blast/Chanachen, Bunakha
		Explosives magazine located with 500m setback from human occupancy	BHPL ESHS / Contractor	Pre-construction/Chanachen farm road junction
	Material Infrastructures	Implementation of Traffic Management Plan	Contractor	Monthly/AH48, Chanachen farm road
		Speed limits enforced (30 km/hr within site, 20 km/hr in village zones)	Contractor	Weekly/Chanachen, Bunakha, Tshimalakha
	Cultural, Religious and Historical Sites	Chance Finds Procedure formulated and workers trained	Contractor / BHPL ESHS	Pre-construction/ all work sites
Construction	Resettlement Plan implementation and livelihood support	Continued implementation of Resettlement Plan (RP) and Livelihood Restoration Plan (LRP)	BHPL ESHS	Quarterly/affected households (30 HH)
		Compensation for any crop damage or property damage resolved	Contractor / CLO	As incidents occur/Chanachen, Bunakha
	Worker safety	Periodic health and safety audits conducted	Contractor	Quarterly;/all work sites
		Medical care and compensation provided for workplace injuries	BHPL ESHS	As incidents occur/all work sites
		Mandatory emission testing for	Contractor	Every 6 months/all project vehicles

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
		all machinery and vehicles every six months		
	Labour influx management and worker Code of Conduct	Labor Influx Management Plan implemented	Contractor	Monthly/Chanachen, Bunakha
		Workers restricted to camps during night-time hours (22:00-06:00)	Contractor	Daily/Labour Camp-1, Labour Camp-2
		Code of Conduct enforcement and penalties for violations	Contractor	Continuous/all work sites
	Material Infrastructures	Traffic Management Plan implementation including speed limits, signage, wheel wash systems	Contractor	Weekly/AH48, Chanachen farm road
		Covered trucks for material transport	Contractor	Daily/haul routes
		Pedestrian plan for safe access to schools implemented	Contractor	Monthly; Chhukha Central School area
	Emergency preparedness and slope stability monitoring	Slope stability monitoring conducted	Contractor / Geotechnical Specialist	Weekly; slopes above Chanachen, cut slopes along Chanachen farm road, Lamche Bja
		Emergency Preparedness and Response Plan implemented and drills conducted	Contractor	Quarterly/ all project area
		Verify pre-blast structural surveys completed	Contractor	Pre-blast/Chanachen, Bunakha villages
	Cultural, Religious and Historical Sites	Vibration monitors installed at Bunakha Lhakhang and Lamche Bja	Contractor / BHPL ESHS	Continuous/Bunakha Lhakhang, Lamche Bja
		Blasting avoided on auspicious religious days	Contractor / BHPL ESHS	Each blast/in coordination with Lams
Operation	Livelihood monitoring for	Continued monitoring of	BHPL ESHS	Annually/affected households (30 HH)

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
	affected households	affected 30 households' income and living standards		
	Worker safety	Implementation of Occupational Health and Safety Plan for operations	BHPL ESHS	Quarterly/powerhouse, dam, transmission lines
		Conduct of regular safety training and drills for all 84 personnel	BHPL ESHS	Semi-annually/powerhouse, dam
		Use of PPE in high-noise areas	BHPL ESHS	Monthly/ powerhouse
	Reservoir safety and public awareness	Conduct of public education and awareness meetings on reservoir safety, flow changes, and warning signals	BHPL ESHS	Annually/ocal communities and schools
	Dam safety inspections and early warning systems	Implementation of Reservoir Operation Manual	BHP	Continuous/reservoir area
		Conduct of regular dam safety inspections	Dam Safety Panel / BHPL	Quarterly//dam structure
		Functionality of early warning system and emergency evacuation plan with annual drills	BHPL ESHS	Annually/downstream communities
		Conduct of annual refresher public awareness meetings	BHPL ESHS	Annually/Chanachen, Bunakha, Nayakha, Tshimalakha
Decommissioning	Worker safety during dam dismantling and demolition	Engagement of Dam Decommissioning Panel of Experts for planning and oversight	BHPL	Pre-decommissioning, project area
		Development of Decommissioning Design and Emergency Preparedness Plans	BHPL	Pre-decommissioning, project area

Project and phase	Issue	Compliance monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation
	Public safety during reservoir drawdown and demolition	Implementation of Decommissioning Design and Emergency Preparedness Plans	BHPL	Throughout decommissioning,project area
	Emergency preparedness and slope stability during decommissioning	Controlled, phased reservoir drawdown with real-time monitoring (max 2.5 m/hr)	BHPL	During drawdown, reservoir area
		Establishment of early warning systems and exclusion zones around demolition areas	BHPL/ Decommissioning Contractor	Before demolition/ dam site, powerhouse
		Conduct of community awareness programs on decommissioning activities and risks	BHPL/ CLO	Pre-decommissioning/ Chanachen, Bunakha, Nayakha

14.3.2 Effects monitoring

Effects monitoring shall be done at each site as detailed in the following sections. The sampling of environmental parameters shall be the responsibility of ESHS. However, they may wish to add some of these sampling obligations as a requirement for the respective contractors to fulfil. May this be the case, the ESMoP to be part of the tender documents and the contracts must clearly state that.

It is recommended to publish the results of the effects monitoring of environmental parameters publicly at BHPL's or DECC's webpages. This will bring to light the expected positive effects of the Bunakha HPP and at the same time sensibilize the residents of the nearby areas to the residual negative impacts.

Table 128: Environmental and Social Monitoring Programme for the Pre-construction of the Bunakha HPP - effects monitoring

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Physical Environment					
Air Quality - Dust and Emissions from Transport, Quarrying, and Batching Plants	Monitor ambient air quality	BHPL ESHS	Weekly during pre-construction; at ANSP-2 Tshimalakha, ANSP-4 Bunakha Lhakhang, ANSP-9 Nayakha, ANSP-10 Chanachen	PM_{10}, $PM_{2.5}$, NO_2, SO_2, O_3, CO; dust deposition	Concentrations within Bhutan ES 2020 limits;
Noise - Quarrying, Crushing, and Batching Operations	Monitor ambient noise levels	BHPL ESHS	Weekly; at Chanachen, Nayakha, Bunakha Lhakhang, Tshimalakha	Leq day (06:00-22:00); Leq night (22:00-06:00)	Daytime ≤ 65 dBA; Night-time ≤ 55 dBA; Chanachen/Nayakha baseline maintained (36-40 dBA)
Water Quality - Community Springs and Wangchhu River	Monitor water quality at upstream, downstream, and community springs	BHPL ESHS	Monthly; at SW-01 (Dam Upstream), SW-02 (Dam Downstream), SW-05, SW-07, SW-09, SW-10	pH, turbidity, TSS, DO, oil & grease, faecal coliform	No exceedance of ES 2020 Class B standards; zero detection of hydrocarbons; 50m buffer zones maintained
Soil Quality - Temporary Land Leasing and Construction Sites	Monitor soil quality	BHPL ESHS	Quarterly; at batching/crushing sites, workshop areas, fuel storage areas	pH, heavy metals (As, Cd, Cr, Pb, Hg, Ni), Total Petroleum Hydrocarbons (TPH)	Soil parameters within baseline ranges; pH 4.65-6.94; no detectable hydrocarbons
Soil Quality - Topsoil Management	Verify topsoil stripping, stockpiling, and preservation	BHPL ESHS	Prior to any clearing; at all disturbance areas	Topsoil stripped depth (300mm); stockpile location; silt fencing; grass seeding	100% of topsoil stripped and stockpiled; stockpiles protected from erosion
Biological Environment					
Forest Habitat Loss & Fragmentation	Monitor extent of vegetation clearing, habitat	BHPL ESHS	Monthly; reservoir area, access roads,	Area cleared (ha), fragmentation patterns, canopy cover	No clearing beyond approved footprint;

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
	fragmentation, and edge effects		transmission corridor, construction sites		progressive restoration implemented
Protected & Medicinal Flora	Monitor survival and regeneration of protected and transplanted flora	BHPL ESHS	Bi-annually; forest areas, disturbed sites	Survival rate (%), regeneration status	≥80% survival of transplanted species
Wildlife Movement & Ecological Corridors	Monitor wildlife movement and corridor functionality	BHPL ESHS	Quarterly, forest corridors, ridge-to-valley paths, road crossings	Camera trap data, wildlife signs, crossing frequency	No significant disruption to movement patterns
Aquatic Ecology (Fish & Macroinvertebrates)	Monitor fish diversity, abundance, and macroinvertebrate communities in river system	BHPL ESHS	Quarterly, upstream intake, dewatered stretch, downstream recovery zone, tributaries	Species richness, CPUE, EPT index, abundance trends	No significant decline (>20%) from baseline; maintenance of key species
Water Quality (Ecological Relevance)	Monitor water quality affecting aquatic habitats	BHPL ESHS	Monthly; upstream, downstream, and discharge points	DO, pH, turbidity, TSS, temperature	No deterioration beyond baseline and national/IFC standards
Riparian Habitat Condition	Monitor condition and regeneration of riparian vegetation	BHPL ESHS	Quarterly, riverbanks, tributary confluences, reservoir margins	Vegetation cover (%), erosion signs, species composition	No net loss of riparian vegetation; successful regeneration
Invasive Alien Species (IAS)	Monitor presence and spread of invasive species in disturbed areas	BHPL ESHS	Quarterly, muck sites, roads, camps, reservoir margins	IAS coverage (%), spread extent	No expansion beyond baseline; effective control measures implemented
Ecosystem Services	Monitor availability of ecosystem services (water, NTFPs, ecological functions)	BHPL ESHS	Annually, community-use zones, forests, river system	Resource availability, community feedback	No significant reduction in ecosystem service availability
Human Environment					

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Land acquisition and compensation	compensation payments are disbursed to all 30 affected households before any land disturbance	BHPL ESHS	Prior to construction commencement; at affected households in Geling and Chapcha Gewogs	Number of households compensated; compensation amount vs entitlement	100% of affected households compensated before land possession
Livelihood restoration	Monitor implementation of livelihood restoration programs for affected households	BHPL ESHS	Quarterly during pre-construction; at affected households	Participation in training programs; alternative income sources established	All affected households enrolled in livelihood restoration programs
Worker safety during site preparation	Inspect worker camps, batching plants, and construction facilities for OHS compliance	BHPL ESHS	Weekly; at all construction facilities, labour camps, and workshop areas	Availability of first aid facilities; PPE usage; safety signage; worker training records	100% of workers trained; PPE compliance; first aid facilities available at all sites
Worker grievance mechanism	Monitor worker GRM is established and functional	BHPL ESHS	Monthly; at all work sites	GRM notice boards; complaint register; resolution timeliness	GRM established before work commences; complaints resolved within 14 days
Community safety - blasting	Conduct pre-blast structural surveys within 500m of quarry site and access road alignment	BHPL ESHS	Before any blasting; at Chanachen and Bunakha villages	Photographic documentation; property owner acknowledgments; pre-existing damage records	100% of structures within 500m documented before blasting
Community safety - explosives magazine	Explosives magazine is located with 500m setback from human occupancy and security measures in place	BHPL ESHS	Monthly; at Chanachen farm road junction (0.64 acres)	Setback distance; fencing; lightning protection; security logs	500m setback maintained; 24/7 security; no unauthorized access

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Traffic safety - road hazards	Monitor implementation of Traffic Management Plan on access roads and highways	BHPL ESHS	Weekly; on Thimphu-Phuentsholing Asian Highway and Chanachen Farm Road	Speed limits (30 km/hr within site, 20 km/hr in village zones); signage; flagmen presence	Speed limits enforced; warning signs installed; no traffic accidents
Cultural heritage - chance finds	Verify that Chance Finds Procedure is formulated and workers are trained	BHPL ESHS	Prior to construction commencement; at all work sites	Worker training records; Chance Finds Procedure document	100% of workers trained before site access
Cultural sensitivity awareness	Monitor cultural sensitivity training completion for all workers	BHPL ESHS	Prior to construction commencement; at all work sites	Training attendance records; awareness session completion	100% of workers completed cultural sensitivity training

Table 129: Environmental and Social Monitoring Programme for the Construction of the Bunakha HPP - effects monitoring

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Physical Environment					
Air Quality - Blasting Dust and Truck Emissions	Monitor ambient air quality	BHPL ESHS	Weekly; at ANSP-1 Labtsakha, ANSP-2 Tshimalakha, ANSP-3 Damsite, ANSP-4 Bunakha Lhakhang, ANSP-5 Quarry Chanachen ANSP-6 Stockyard, ANSP-7 Campsite, ANSP-9 Nayakha, ANSP-10 Chanachen.	PM_{10}, $PM_{2.5}$, NO_2, SO_2, O_3, CO	Concentrations within Bhutan ES 2020 limits; vehicle emissions tested every 6 months
Air Quality - Muck Transport	Verify that all haul trucks are covered and wheel-washing facilities operational	BHPL ESHS	Daily; at MD-2, MD-4 exits, powerhouse exit	Truck cover compliance; wheel wash usage; visible dust plumes	100% of haul trucks covered; wheel wash used; no visible dust plumes
Noise - Blasting Operations	Monitor noise and vibration levels during blasting	BHPL ESHS	During each blast; at Bunakha Lhakhang, Lamche Bja, Chanachen houses	Peak particle velocity (PPV); noise levels (Lmax); blast times	blasting restricted to daytime window (12:00-13:00)
Noise - Construction and Traffic	Monitor ambient noise levels	BHPL ESHS	Weekly; at Chanachen, Nayakha, Bunakha Lhakhang, Tshimalakha	Leq day (06:00-22:00); Leq night (22:00-06:00)	Daytime ≤ 65 dBA; Night-time ≤ 55 dBA; heavy haulage restricted to daytime hours
Water Quality - River Flow and Sedimentation	Monitor environmental flow and water quality	BHPL ESHS	Continuous; at SW-01 and SW-02; during diversion tunnel operation	Flow rate (m^3/s); pH, turbidity, TSS, DO	Minimum environmental flow (30% of lean season flows) maintained; TSS within baseline

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Water Quality - Muck Disposal Sites	Monitor sedimentation pond effectiveness and downstream water quality	BHPL ESHS	Weekly; at MD-1, MD-2, MD-4 toe; SW-2 monitoring point	Sedimentation pond condition; turbidity at SW-2; TSS	Sedimentation ponds functional; no exceedance of water quality standards
Soil Quality - Muck Disposal and Chemical Spills	Monitor soil quality at disposal sites and high-risk areas	BHPL ESHS	Monthly; at MD-1, MD-2, MD-4; powerhouse; workshop areas	Visual inspection; soil sampling for pH, heavy metals, TPH	No visible spills; soil parameters within baseline; secondary containment intact
Soil Quality - Topsoil Conservation	Verify topsoil conservation and progressive rehabilitation	BHPL ESHS	Quarterly; at all disturbed areas	Topsoil stockpile condition; progressive revegetation	Topsoil preserved; completed slopes revegetated within 3 months
Land and Geology - Blasting Vibration	Monitor vibration impacts on structures and slopes	BHPL ESHS	During each blast; at Bunakha Lhakhang, Lamche Bja, Chanachen houses	PPV readings; structural condition surveys; slope stability	PPV within safe limits; no damage to structures; slopes stable
Land and Geology - Muck Disposal Site Stability	Monitor slope stability at disposal sites	BHPL ESHS	Weekly; after heavy rainfall; at MD-1, MD-2, MD-4	Visual signs of instability; toe wall condition; drainage functionality	No slope failures; toe walls intact; drainage functional
River Morphology - River Flow and Sediment	Monitor river flow, sediment transport, and channel morphology	BHPL ESHS	Continuous; at diversion tunnels and river course	Flow rate; sediment load; channel condition	Minimum environmental flow maintained; no channel degradation
Biological Environment					
Forest Habitat Loss & Fragmentation	Monitor extent of vegetation clearing, habitat fragmentation, and edge effects	BHPL ESHS	Monthly; reservoir area, access roads, transmission corridor, construction sites	Area cleared (ha), fragmentation patterns, canopy cover	No clearing beyond approved footprint; progressive restoration implemented

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Aquatic Ecology (Fish & Macroinvertebrates)	Monitor fish diversity, abundance, and macroinvertebrate communities in river system	BHPL ESHS	Quarterly, upstream intake, dewatered stretch, downstream recovery zone, tributaries	Species richness, CPUE, EPT index, abundance trends	No significant decline (>20%) from baseline; maintenance of key species
Environmental Flow Compliance	Monitor environmental flow release and seasonal variability	BHPL ESHS	Continuous; intake and downstream of diversion reach	Flow discharge (m^3/s), seasonal flow variation	100% compliance with approved environmental flow regime
Water Quality (Ecological Relevance)	Monitor water quality affecting aquatic habitats	BHPL ESHS	Monthly; upstream, downstream, and discharge points	DO, pH, turbidity, TSS, temperature	No deterioration beyond baseline and national/IFC standards
Riparian Habitat Condition	Monitor condition and regeneration of riparian vegetation	BHPL ESHS	Quarterly, riverbanks, tributary confluences, reservoir margins	Vegetation cover (%), erosion signs, species composition	No net loss of riparian vegetation; successful regeneration
Wildlife Movement & Ecological Corridors	Monitor wildlife movement and corridor functionality	BHPL ESHS	Quarterly, forest corridors, ridge-to-valley paths, road crossings	Camera trap data, wildlife signs, crossing frequency	No significant disruption to movement patterns
Terrestrial Mammals	Monitor presence and activity of key mammalian species	BHPL ESHS	Quarterly, forested slopes, reservoir surroundings	Species presence, abundance trends	Stable or increasing trends of key species
Avifauna (including threatened species)	Monitor bird diversity, nesting, and disturbance	BHPL ESHS	Seasonal (pre-monsoon, post-monsoon); riparian zones, cliffs, forest canopy	Species richness, nesting activity, population trends	No decline in conservation-significant species
Herpetofauna	Monitor amphibian and reptile diversity and habitat condition	BHPL ESHS	Bi-annually; moist forest floor, stream banks, seepage zones	Species diversity, habitat condition indicators	No significant decline in habitat suitability
Invasive Alien Species (IAS)	Monitor presence and spread of	BHPL ESHS	Quarterly, muck sites, roads, camps, reservoir margins	IAS coverage (%), spread extent	No expansion beyond baseline; effective

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
	invasive species in disturbed areas				control measures implemented
Flora (Rescued/ Transplanted)	Monitor Survival of rescued and transplanted flora	BHPL ESHS	Bi-annually	Survival rate	≥80% survival
Pollinators & Insects	Monitor pollinator diversity and activity levels	BHPL ESHS	Seasonal; flowering zones, forest edges, riparian vegetation	Species diversity, abundance	No significant decline from baseline
Ecosystem Services	Monitor availability of ecosystem services (water, NTFPs, ecological functions)	BHPL ESHS	Annually, community-use zones, forests, river system	Resource availability, community feedback	No significant reduction in ecosystem service availability
Floodplain & Aquatic–Terrestrial Interface Ecology	Monitor ecological condition of floodplain and interface zones	BHPL ESHS	Quarterly, riverbanks, seasonal inundation zones	Habitat condition, species presence	No degradation of ecological functions
Restoration Areas	Monitor afforestation & restoration	BHPL ESHS	Quarterly	Survival %, cover	≥80% survival
Forest Habitat Loss & Fragmentation	Monitor extent of vegetation clearing, habitat fragmentation, and edge effects	BHPL ESHS	Monthly; reservoir area, access roads, transmission corridor, construction sites	Area cleared (ha), fragmentation patterns, canopy cover	No clearing beyond approved footprint; progressive restoration implemented
Human Environment					
Resettlement Plan implementation	Verify that all compensation and livelihood support is provided to affected households	BHPL ESHS	Quarterly; at affected households in Geling and Chapcha Gewogs	Compensation disbursement records; livelihood program enrollment; income levels	100% of affected households restored or improved livelihoods; income levels at or above baseline

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Worker OHS compliance	Monitor implementation of Occupational Health and Safety Plan at all work sites	BHPL ESHS	Weekly; at dam site, tunnels, powerhouse, quarry, batching plants	Accident/incident reports; PPE compliance; safety training records; first aid availability	Zero fatalitiesof workers with valid safety training
Labor Management Plan compliance	Verify worker contracts, working conditions, and grievance mechanism	BHPL ESHS	Monthly; at all work sites and labour camps	Written contracts; wage records; GRM usage; accommodation inspections	100% of workers have written contracts; wages paid on time; accommodation meets IFC/EBRD standards
Labour influx management	Monitor implementation of Labor Influx Management Plan and worker Code of Conduct	BHPL ESHS	Monthly; at labour camps, Chanachen, Bunakha villages	Worker camp records; Code of Conduct violations; community complaints	Zero GBV/SEAH incidents; no poaching or unauthorized forest entry; community complaints resolved
Worker camp sanitation and waste	Inspect sanitation facilities, waste management, and water treatment at labour camps	BHPL ESHS	Monthly; at Labour Camp-1and Labour Camp-2	STP/septic tank functionality; waste segregation; water quality tests	No discharge of untreated sewage; 100% of waste disposed at approved sites; potable water provided
Community health - communicable diseases	Monitor health awareness programs and disease prevention measures	BHPL ESHS	Monthly; at labour camps and nearby villages	Health awareness session records; condom distribution; STI/STD screening participation	Awareness programs conducted quarterly; condoms available at camps; no outbreak of STIs/STDs
Traffic management - road safety	Monitor compliance with Traffic Management Plan	BHPL ESHS	Weekly; on haul routes, access roads, near Chhukha Central School and Tshimalakha Hospital	Speed compliance; covered trucks; wheel wash system; pedestrian crossings	Speed limits (30 km/hr within site, 20 km/hr in village zones) maintained; no traffic accidents involving project vehicles

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Structural damage from blasting	Monitor vibration levels and structural integrity of sensitive structures	BHPL ESHS	During each blast; at Bunakha Lhakhang, Lamche Bja, Chanachen houses	Peak particle velocity (PPV) readings; vibration monitoring records	no damage claims
Emergency preparedness	Verify that Emergency Preparedness and Response Plan is implemented and drills conducted	BHPL ESHS	Quarterly; at all work sites and downstream communities	Emergency drill records; early warning system functionality; evacuation route signage	Emergency drills conducted quarterly; early warning system tested monthly; all workers trained
Slope stability monitoring	Monitor slopes for signs of instability	BHPL ESHS	Weekly; at slopes above Chanachen, cut slopes along Chanachen farm road, Lamche Bja	Visual inspections; inclinometer readings; crack monitoring	No landslides induced by project activities
Cultural heritage - vibration impacts	Monitor vibration levels at cultural sites during blasting	BHPL ESHS	During each blast; at Bunakha Lhakhang and Lamche Bja	Vibration readings; PPV records; structural condition surveys	no damage to cultural structures
Chance finds implementation	Verify that Chance Finds Procedure is followed during excavation	BHPL ESHS	Continuous during excavation; at all excavation areas	Chance find log; stop work records; authority notifications	100% of chance finds reported and managed per procedure

Table 130: Environmental and Social Monitoring Programme for the Operation of the Bunakha HPP - effects monitoring

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Physical Environment					
Noise - Turbine Hall and Vehicular Movements	Monitor noise levels at powerhouse and sensitive receptors	BHPL ESHS	Quarterly; at turbine hall, Chanachen, Nayakha, Bunakha Lhakhang, Tshimalakha	Leq (turbine hall); Leq day/night (communities)	Turbine hall noise ≤ 85 dBA (8-hour TWA); community noise ≤ 65 dBA day, 55 dBA night
Land and Geology - Reservoir Drawdown	Monitor reservoir drawdown rate and bank erosion	BHPL ESHS	Weekly during drawdown; at reservoir margins	Drawdown rate (m/hr); visual bank erosion; slope stability	Drawdown rate ≤ 2.5 m/hr; no bank erosion; slopes stable
Land and Geology - Reservoir Sedimentation	Conduct bathymetric surveys to monitor sediment deposition	BHPL ESHS	Every 5 years; at reservoir	Sediment deposition depth; reservoir capacity loss	Sediment deposition within predicted range
River Morphology - Downstream Flow	Monitor flow releases and coordinate with cascade operators	BHPL ESHS	Continuous; at downstream monitoring points	Flow rate; communication logs with Chhukha and Tala HPPs	Environmental flow maintained; cascade coordination documented
Biological Environment					
Environmental Flow	Monitor flow regime	BHPL	Continuous	Flow discharge	100% compliance
Aquatic Ecology (Fish & Macroinvertebrates)	Monitor fish diversity, abundance, and macroinvertebrate communities in river system	BHPL ESHS	Quarterly, upstream intake, dewatered stretch, downstream recovery zone, tributaries	Species richness, CPUE, EPT index, abundance trends	No significant decline (>20%) from baseline; maintenance of key species
Water Quality (Ecological Relevance)	Monitor water quality affecting aquatic habitats	BHPL ESHS	Monthly; upstream, downstream, and discharge points	DO, pH, turbidity, TSS, temperature	No deterioration beyond baseline and national/IFC standards
Riparian Habitat Condition	Monitor condition and regeneration of riparian vegetation	BHPL ESHS	Quarterly, riverbanks, tributary confluences, reservoir margins	Vegetation cover (%), erosion signs, species composition	No net loss of riparian vegetation; successful regeneration

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Wildlife Movement & Ecological Corridors	Monitor wildlife movement and corridor functionality	BHPL ESHS	Quarterly, forest corridors, ridge-to-valley paths, road crossings	Camera trap data, wildlife signs, crossing frequency	No significant disruption to movement patterns
Terrestrial Mammals	Monitor presence and activity of key mammalian species	BHPL ESHS	Quarterly, forested slopes, reservoir surroundings	Species presence, abundance trends	Stable or increasing trends of key species
Invasive Alien Species (IAS)	Monitor presence and spread of invasive species in disturbed areas	BHPL ESHS	Quarterly, muck sites, roads, camps, reservoir margins	IAS coverage (%), spread extent	No expansion beyond baseline; effective control measures implemented
Ecosystem Services	Monitor availability of ecosystem services (water, NTFPs, ecological functions)	BHPL ESHS	Annually, community-use zones, forests, river system	Resource availability, community feedback	No significant reduction in ecosystem service availability
Habitat Restoration & Re-vegetation	Monitor effectiveness of restoration and afforestation activities	BHPL ESHS	Quarterly, restored areas, muck disposal sites, slopes	Survival rate (%), vegetation cover, species diversity	≥80% survival; successful habitat recovery
Critical Habitat - key species	Monitor population status and habitat condition of species meeting ADB Critical Habitat criteria	BHPL ESHS / DoFPS	Annually; forested slopes, reservoir margins, riparian zones, ridge-to-valley corridors	Species presence/absence, population trend, habitat condition score	Stable or increasing population trends for all Critical Habitat species
Human Environment					
Livelihood restoration - affected households	Monitor income and living standards of 30 affected households	BHPL ESHS	Annually; at affected households in Geling and Chapcha Gewogs	Household income; asset ownership; food security; employment status	All affected households maintain or improve living standards compared to pre-project baseline

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Worker OHS - powerhouse operations	Monitor occupational health and safety compliance for 84 operational staff	BHPL ESHS	Monthly; at powerhouse and associated facilities	OHS training records; PPE compliance; incident reports; health checkup records	Zero fatalities; annual health checkups for all workers
Community safety - reservoir and flow changes	Monitor public awareness and safety incidents related to flow changes	BHPL ESHS	Semi-annually; at local communities and schools	Public awareness meeting records; warning signage condition; siren functionality; incident reports	Zero drowning incidents; community awareness of flow change risks; warning sirens functional
Emergency preparedness - dam safety	Monitor dam safety inspections and early warning systems	Dam Safety Panel / BHPL ESHS	Quarterly; at dam, reservoir, and downstream communities	Dam safety inspection reports; early warning system tests; emergency drill records	All dam safety recommendations implemented; early warning system tested monthly; annual drills conducted
Emergency preparedness - natural disasters	Monitor emergency preparedness and response drills	BHPL ESHS	Annually; at project site and downstream communities	Drill records; response times; equipment functionality	Annual drills conducted; response plans updated; equipment maintained
Material infrastructure - transmission line	Monitor transmission line maintenance and bird safety	BHPL ESHS/ BPC	Semi-annually; along transmission line corridor	Vegetation clearance records; bird diverter condition; bird mortality surveys	Bird diverters installed at high-risk sections; no bird mortality reported

Table 131: Environmental and Social Monitoring Programme for the Decomissioning of the Bunakha HPP - effects monitoring

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Physical Environment					
Air Quality - Demolition Dust	Monitor air quality during demolition activities	BHPL ESHS	Daily during demolition; at Chanachen, Bunakha, Nayakha	PM_{10}, $PM_{2.5}$; visible dust	Water spraying applied; visible dust controlled; PPE used by workers
Land and Geology - Reservoir Drawdown	Monitor drawdown rate and downstream flooding risk	BHPL ESHS	Daily during drawdown; at reservoir and downstream communities	Drawdown rate (m/hr); water level; early warning system functionality	Drawdown rate ≤ 2.5 m/hr; early warning systems operational; no downstream flooding
Land and Geology - Slope Stability	Monitor slope stability during reservoir drawdown and dismantling	BHPL ESHS	Weekly; after heavy rainfall; at reservoir margins, cut slopes, disposal sites	Visual signs of instability; erosion; landslide risk	No slope failures; erosion control measures effective
Land and Geology - Soil Erosion	Monitor erosion on denuded slopes and reclaimed areas	BHPL ESHS	Monthly; during monsoon; at all disturbed areas	Gully formation; sediment transport; erosion control measures	No gully formation; erosion control measures effective; sediment contained
Land and Geology - Sediment Release	Monitor downstream water quality during sediment flushing	BHPL ESHS	Daily during flushing; at downstream monitoring points (SW-02, Chhukha Dam)	Turbidity; TSS; sediment concentration	Sediment release within predicted ranges; no exceedance of water quality standards
Biological Environment					
Habitat Restoration	Monitor effectiveness of restoration	BHPL ESHS	Post decommissioning	Survival rate (%), vegetation cover, species diversity	Successful habitat recovery
Aquatic Ecology (Fish & Macroinvertebrates)	Monitor fish diversity, abundance, and macroinvertebrate communities in river system	BHPL ESHS	Periodic	Species richness, CPUE, EPT index, abundance trends	Improving trends

Issue	Effects monitoring measures	Responsibility for implementation	Timing and/or frequency and/or location of implementation	Indicator Parameters	Performance Indicators
Water Quality (Ecological Relevance)	Monitor water quality affecting aquatic habitats	BHPL ESHS	During dismantling	Turbidity, TSS,	Within Limits
Riparian Habitat Condition	Monitor condition and regeneration of riparian vegetation	BHPL ESHS	Post Phase	Vegetation cover (%), erosion signs, species composition	Stable recovery
Wildlife Movement & Ecological Corridors	Monitor wildlife movement and corridor functionality	BHPL ESHS	Periodic	Movement patterns	Connectivity restored
Ecosystem Services	Monitor availability of ecosystem services (water, NTFPs, ecological functions)	BHPL ESHS	Annual	Resource availability	Restored to baseline
Human Environment					
Dam decommissioning safety	Monitor implementation of Decommissioning Design and Emergency Preparedness Plans	BHPL ESHS	Continuous during decommissioning; at dam site, reservoir, and downstream communities	Drawdown rate (m/hr); slope stability; early warning system functionality	Drawdown rate ≤2.5 m/hr; no slope failures; early warning systems operational
Worker safety during demolition	Monitor OHS compliance during demolition activities	BHPL ESHS	Weekly; at dam, powerhouse, and demolition areas	PPE usage; safety training records; incident reports	Zero fatalities
Community safety - flooding	Monitor early warning system and community awareness	BHPL ESHS	During drawdown; at downstream communities (Chanachen, Bunakha, Nayakha)	Warning siren tests; community meeting records; evacuation drills	Early warning system functional; community aware of evacuation procedures; no flooding incidents

15 Environmental Valuation

Environmental valuation is the practice of assigning monetary values to nature and its associated functions, also referred to as Ecosystem Services (ES), to assess the contribution of these ecosystem services to the well-being of humans in a sustainable manner (Eaton, 2017).

For the BHPP, environmental valuation has been undertaken to estimate the economic value of key ecosystem services associated with the project area. The valuation focuses on provisioning, regulating, and supporting services derived from forest ecosystems, riverine systems, and associated landscapes within the project's area of influence.

In accordance with Bhutan-specific studies, the valuation adopts the mean ecosystem service values for different land cover types determined by Kubiszewski et al. (2013). This approach provides a robust and context-relevant basis for estimating ecosystem service values, as it integrates global ecosystem valuation datasets with Bhutan's land cover characteristics and ecological productivity (Kubiszewski, Costanza, Dorji, Thoennes, & Tshering, 2013).

The BHPP area, located within the Wangchhu river basin, is predominantly characterized by forest ecosystems, with additional contributions from riverine systems, limited agricultural land, and minor built-up areas. Forest ecosystems form the dominant ecological component and provide high-value regulating and supporting ecosystem services.

The land cover distribution used in this valuation is derived from the Updated DPR (Table 5: Land requirement for submergence and project components), focusing on the inundation area representing the primary zone of permanent ecosystem service loss. Temporary construction areas and ancillary facilities are excluded to avoid overestimation of ecosystem service values.

The valuation applies mean ES coefficients to DPR-aligned land cover categories to estimate annual ecosystem service values. The results indicate that forest ecosystems contribute the largest share of environmental value, primarily due to their role in carbon sequestration, slope stabilization, erosion control, hydrological regulation, and biodiversity conservation. Aquatic ecosystems, although smaller in extent, contribute essential ecological services including habitat provision, nutrient cycling, and maintenance of riverine ecological integrity (Millennium Ecosystem Assessment , 2005).

Based on DPR-aligned land cover distribution, the total annual environmental value of the BHPP area is estimated to be in the range of approximately Nu. 350–438 million per year. This reflects the high ecological and hydrological importance of mid-Himalayan ecosystems, particularly in steep terrain where regulating services such as erosion control and watershed protection are critical.

It should be noted that these values represent gross ecosystem service estimates and do not directly translate into economic losses, as many ecosystem functions are partially retained, restored, or compensated through mitigation and offset measures.

These ecosystem services play a critical role in reducing soil erosion and landslide risks, maintaining water quality and hydrological balance, supporting biodiversity, and regulating climate through carbon sequestration. Such services are not typically captured in market transactions but are fundamental to environmental sustainability and human well-being (Millennium Ecosystem Assessment , 2005).

Accordingly, the findings reinforce the importance of applying the mitigation hierarchy (avoid–minimize–restore–offset) as required under international best practice, including IFC Performance Standard 6 (IFC, 2012) and ADB Safeguard Policy Statement (ADB, 2009). Measures such as avoidance of high-value habitats, minimization of forest clearance, compensatory afforestation at a 1:1 ratio, biodiversity conservation planning, and ecological restoration are essential to ensure that ecosystem service losses are minimized and, where feasible, offset.

The valuation is subject to limitations, including use of average ecosystem service coefficients, assumptions on land cover homogeneity, and exclusion of temporal variations. The results should therefore be interpreted as indicative estimates supporting decision-making rather than precise economic valuations.

Table 132: Environmental Valuation of BHPP Area (Based on Kubiszewski et al., 2013)

SN	Land Cover Type	Dominant Ecosystem Services	ES Value (Nu. / ha/ year)	Estimated Area (ha)	Estimated Value (Nu. /year)	Remarks
1	Forest land	Carbon sequestration, erosion control, habitat provision, hydrological regulation	900,000 – 1,100,000	349.24	314,316,000 – 384,164,000	Dominant component of inundation area
2	Riverine/ Water bodies	Habitat provision, nutrient cycling, water regulation	400,000 – 600,000	88.37	35,348,000 – 53,022,000	Wangchhu reservoir
3	Agriculture land	Provisioning services, soil functions	100,000 – 200,000	2.20	220,000 – 440,000	Limited extent
4	Built-up / Modified land	Minimal ecosystem services	50,000 – 100,000	0.29	14,500 – 29,000	Negligible
	Total			≈ 440.11 ha	349,898,500 – 437,655,000	≈ Nu. 350–438 million/ year

15.1 Benefits of Environmental Conservation and Protection in Bunakha HPP Area

Environmental conservation in the Bunakha HPP area provides significant long-term ecological, hydrological, climatic, and socio-economic benefits. The predominantly natural habitats support biodiversity, maintain ecosystem processes, and ensure continued provision of ecosystem services essential for environmental stability (Millennium Ecosystem Assessment , 2005).

The forest ecosystems contribute to slope stabilization, erosion control, and landslide risk reduction, which are particularly important in the steep terrain of the Wangchhu basin. They also play a critical role in maintaining hydrological balance by regulating runoff, enhancing groundwater recharge, and preserving water quality.

Aquatic ecosystem conservation supports ecological integrity of the river system, including habitat provision for fish and aquatic species, nutrient cycling, and maintenance of environmental flows (IFC, 2012). These functions are critical for sustaining downstream biodiversity and ecosystem health.

Environmental conservation also contributes to carbon sequestration and climate regulation, supporting Bhutan's carbon-neutral development pathway. In addition, natural landscapes provide cultural, aesthetic, and eco-tourism value, contributing to long-term sustainable development.

Overall, conservation enhances ecosystem resilience, reduces environmental risks, and supports sustainable livelihoods, making it a critical component of environmental management (ADB, 2009).

15.2 Benefits from Bunakha Hydropower Project

The BHPP is expected to generate substantial economic, social, infrastructure, and climate-related benefits at local, regional, and national levels.

Based on the Updated DPR, the project is expected to generate approximately 746 GWh of electricity annually, representing the direct energy output of Bunakha HPP and additional 632 GWh/year downstream cascade benefit (system-level); however, these additional benefits are considered system-level gains and are not included in the direct project output.

At an indicative tariff of Nu. 5.0/kWh, the annual revenue from direct electricity generation is estimated at approximately Nu. 3,730 million per year. This value is indicative and subject to tariff structures, export agreements, and seasonal pricing mechanisms.

The project will create significant employment opportunities during both construction and operation phases. Construction activities are expected to generate substantial temporary employment, while long-term operational employment will support sustained livelihoods and local economic development.

Infrastructure improvements, including access roads and construction facilities, will enhance regional connectivity and facilitate economic growth in surrounding areas.

From a climate perspective, Bunakha HPP will contribute to greenhouse gas (GHG) emission reduction by displacing fossil fuel-based electricity generation. The estimated avoided emissions of approximately 572,352 tCO_2e per year are based on conservative emission factors and are indicative of the project's contribution to low-carbon development.

Table 133: Benefits from BHP

SN	Benefit Category	Description	Estimated Value/ Outcome	Remarks
1	Electricity generation	Annual energy production	746 GWh/year	DPR based
2	Revenue generation	Electricity export	Nu. ~3,730 million/year	Based on Nu. 5.0/kWh

SN	Benefit Category	Description	Estimated Value/ Outcome	Remarks
3	Employment (construction)	Temporary jobs	High	To be confirmed during detailed planning
4	Employment (operation)	Permanent jobs	Moderate	Long-term
5	Infrastructure development	Roads and utilities	High	Regional benefit
6	Local economic growth	Business opportunities	Moderate - High	Indirect benefits
7	Energy security	Renewable energy contribution	High	National benefit
8	GHG reduction	Avoided emissions	572,352 tCO2e/year	Clean energy benefit

15.3 Comparison of Benefits of Environmental Conservation and Bunakha HPP

A comparison of environmental conservation and hydropower development indicates that both provide important but distinct benefits. Environmental conservation delivers long-term ecological stability, biodiversity support, watershed protection, and climate regulation (Millennium Ecosystem Assessment , 2005), while hydropower development provides direct economic returns, energy generation, and infrastructure development (ADB, 2009).

In the case of BHPP, these trade-offs can be effectively managed through implementation of the mitigation hierarchy and associated environmental management plans, including the Biodiversity Management Plan (BMP), Fisheries Conservation and Management Plan (FCMP), and Compensatory Afforestation Plan, consistent with IFC Performance Standard 6 (IFC, 2012). Overall, the BHPP demonstrates that sustainable hydropower development can generate substantial clean energy and economic benefits while maintaining environmental sustainability, provided that mitigation, biodiversity conservation, 1:1 compensatory tree plantation, and long-term monitoring measures are effectively implemented.

With these measures in place, residual impacts are expected to be reduced to acceptable levels, allowing a balance between environmental protection and development benefits.

Table 134: Comparative Assessment

Criteria	Environmental Conservation	Bunakha HPP Development
Type of benefits	Ecological and indirect socio-economic	Economic, social and energy
Time scale	Long-term	Medium to long-term
Biodiversity impact	Positive	Localized impact (mitigable)
Ecosystem services	Maintained	Partially altered
Economic return	Low direct	High
Climate benefit	Carbon sequestration	Clean energy generation
Risk level	Low	Moderate (manageable)
Sustainability	High	High with mitigation

Table 135: Trade-off and Mitigation Balance

Impact	Without Mitigation	Mitigation Measures	Residual Impact
Forest loss	Significant	Compensatory afforestation, restoration	Low (Post mitigation)
Habitat disturbance	High	BMP, wildlife measures	Low
Aquatic impact	Flow alteration	Environmental flow, FCMP	Low
Soil erosion	High	Bioengineering, drainage	Low
Community pressure	Moderate	CESHSMP, engagement	Low

Table 136:: Net Benefit Summary

Component	Conservation	Bunakha HPP	Outcome
Ecological value	High	Moderate impact	Balanced
Economic value	Low	Very High	Positive
Social value	Moderate	High	Positive
Climate benefit	High	High	Strong positive
Overall	High importance	High importance	Sustainable with mitigation

Overall, the BHPP demonstrates that sustainable hydropower development can generate substantial clean energy and economic benefits while maintaining environmental sustainability, if mitigation, biodiversity conservation, compensatory afforestation, and long-term monitoring measures are effectively implemented.

16 Overall Findings, Conclusion and Recommendations

16.1 Overall Findings

The Draft Environmental and Social Impact Assessment (ESIA) for the BHPP presents a comprehensive assessment of the environmental and social baseline conditions, potential project impacts, and proposed mitigation and management measures associated with the development of the 180 MW hydropower project in the Wangchu River Basin, Bhutan. The ESIA has been prepared in consideration of the Royal Government of Bhutan regulatory framework and the requirements of the Asian Development Bank (ADB) Safeguard Policy Statement (2009), supported by specialist studies on biodiversity, critical habitat, environmental flows, climate change, social impacts, stakeholder engagement, gender and vulnerability, and resettlement.

The assessment confirms that the Project is associated with significant environmental and social sensitivities due to:

- its location within an ecologically important river basin
- proximity to sensitive aquatic and terrestrial habitats
- the presence of species of conservation significance
- large-scale civil construction activities
- land acquisition and livelihood impacts
- and the cumulative hydropower development context within the Wangchu basin.

The ESIA identifies both positive and adverse impacts associated with the Project. Key anticipated positive impacts include:

- renewable energy generation
- contribution to Bhutan's carbon neutrality objectives
- improved dry-season flow regulation for downstream hydropower projects
- employment opportunities
- local economic stimulation
- infrastructure development
- and long-term national revenue generation.

Potential adverse impacts identified include:

- alteration of river hydrology and aquatic habitats
- impacts on fish and macroinvertebrate communities
- forest loss and habitat fragmentation
- construction-related erosion, sedimentation, dust, noise, and waste generation
- occupational and community health and safety risks
- labor influx-related social risks
- impacts on land and assets
- impacts on vulnerable households
- and cumulative impacts associated with the Wangchhu hydropower cascade.

The ESIA concludes that most adverse impacts can be avoided, minimized, mitigated, or managed to acceptable levels through implementation of:

- the Environmental and Social Management Plan (ESMP)
- Biodiversity Management Plan

- Environmental Flow measures
- Gender and Vulnerability Action Plan
- Stakeholder Engagement Plan
- Resettlement Plan
- Climate Risk Management measures
- and associated sub-management plans.

The Critical Habitat Screening and Critical Habitat Assessment identified biodiversity sensitivities requiring careful implementation of mitigation principles, adaptive biodiversity management, long-term monitoring, and continued coordination with relevant authorities and stakeholders.

The Project incorporates climate adaptation and dam safety considerations within the Climate Risk Assessment and Management Plan.

16.2 Conclusion

Based on the findings of the environmental and social assessment, the BHPP is considered technically feasible and environmentally and socially manageable, provided that the mitigation, monitoring, compensation, and adaptive management measures identified in the ESIA and associated management plans are effectively implemented throughout all Project phases.

Although the Project will result in significant environmental and social impacts typical of large hydropower developments, the ESIA demonstrates that these impacts can be reduced to acceptable levels through:

- strict implementation of mitigation measures
- effective institutional coordination
- continued stakeholder engagement
- and robust environmental and social monitoring

The assessment further concludes that:

- no legally designated protected areas will be directly inundated by the Project
- the Project does not trigger ADB Indigenous Peoples safeguards
- and most identified impacts are mitigable with implementation of the proposed management plans.

16.3 Recommendations

The following key recommendations are made for the BHPP:

- Finalize and implement all Environmental and Social Management Plans (ESMPs), sub-plans, and monitoring frameworks prior to commencement of construction activities

Ensure that all mitigation measures identified in the ESIA are fully integrated into

- contractor obligations
- and supervision requirements

Implement the Environmental Flow regime and associated monitoring program throughout the Project lifecycle to maintain downstream ecological functions and community water uses.

Maintain continuous stakeholder engagement and disclosure throughout Project implementation, including regular consultation with affected communities, and relevant authorities.

Continue cumulative impact monitoring and coordination with other hydropower projects within the Wangchhu River Basin to manage basin-wide environmental and social risks.

Ensure that all required permits, clearances, and approvals are obtained prior to commencement of construction activities.

17 References

- **Asian Development Bank (ADB), 2009:** Safeguard Policy Statement. Manila: ADB.
- **American Public Health Association (APHA), American Water Works Association (AWWA), & Water Environment Federation (WEF), 2017**: Standard Methods for the Examination of Water and Wastewater (23rd ed.). Washington, DC: APHA Press.
- **Arnold, J. G., Srinivasan, R., Muttiah, R. S., & Williams, J. R. (1998):** Large area hydrologic modeling and assessment: Part I. Model development. Journal of the American Water Resources Association, 34(1), 73–89. https://doi.org/10.1111/j.1752-1688.1998.tb05961.x
- **Bhatta, B., Shrestha, S., Shrestha, P. K., & Talchabhadel, R. (2019):** Evaluation and application of a SWAT model to assess the climate change impact on the hydrology of the Himalayan River Basin. Catena, 181, 104082. https://doi.org/10.1016/j.catena.2019.104082
- **Bhatta, B., Shrestha, S., Shrestha, P. K., & Talchabhadel, R. (2020):** Modelling the impact of past and future climate scenarios on streamflow in a highly mountainous watershed: A case study in the West Seti River Basin, Nepal. Science of the Total Environment, 140156. https://doi.org/10.1016/j.scitotenv.2020.140156
- **Bhutan National Commission for UNESCO. (2012, August 3):** Jigme Dorji National Park (JDNP) (Ref.: 5699). UNESCO World Heritage Centre. https://whc.unesco.org/en/tentativelists/5699/
- **BirdLife International (2026)** Site factsheet: Kamji. Downloaded from https://datazone.birdlife.org/site/factsheet/15210-kamji on 01/04/2026
- **Canadian Council of Ministers of the Environment (CCME), 1999, with updates:** Canadian soil quality guidelines for the protection of environmental and human health. Winnipeg, MB: CCME.
- **Department of Environment and Climate Change. (2023):** Bhutan's long-term low greenhouse gas emission and climate resilient development strategy (LTS). Ministry of Energy and Natural Resources, Royal Government of Bhutan.
- **Divisional Forest Office (2023):** conservation management plan of biological corridor 01(July 2023 to June 2033), Department of Forests and Park Services, Ministry of Energy and Natural Resources, Royal Government of Bhutan, Paro.
- **Divisional Forest Office (2024):** Conservation Management Plan for Biological Corridor 02, Connecting Jigme Singye Wangchuck National Park and Royal Botanical Park, Divisional Forest Office, Wangdue, Department of Forests and Park Services.
- **DLA, Maxwell Stamp Ltd., & APECS, 2025:** TA-6916 BHU: Master Plan for National Highways Connectivity. Report 8 Final Report. Asian Development Bank.
- **DoFPS, 2020:** Biodiversity Monitoring and Social Survey Protocol of Bhutan. Nature Conservation Division, Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan.
- **D. Shrestha et al. (2023):** Dibesh Shrestha et al., Rainfall extremes under future climate change with implications for urban flood risk in Kathmandu, Nepal, International Journal of Disaster Risk Reduction, Elsevier, 9 September 2023
- **Dunning, S. A., Rosser, N. J., Petley, D. N., & Massey, C. R. (2006)**. Formation and failure of the Tsatichhu landslide dam, Bhutan. Landslides, 3(2), 107–113. https://doi.org/10.1007/s10346-005-0032-x
- **EBRD, 2019:** European Bank for Reconstruction and Development E&S Policy. Available at : https://www.ebrd.com/news/publications/policies/environmental-and-social-policy-esp.html
- **EIB, 2022:** European Investment Bank E&S Standards. Available at: https://www.eib.org/en/publications/eib-environmental-and-social-standards

- **Eyring *et al*. 2016:** V. Eyring et al.: Overview of the Coupled Model Intercomparison Project Phase (CMIP6) experimental design and organization, 26 May 2016, Copernicus Publications on behalf of the European Geosciences Union.
- **IFC, 2012:** International Finance Corporation's guidance notes: performance standards on environmental and social sustainability (English). IFC E&S Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/454371481192973684
- **IFC, 2013:** Good Practice Handbook Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets, August 2013
- **IFC, 2021:** Trishuli Assessment Tool Field Manual - A Standardized Methodology for Freshwater Aquatic Biodiversity Sampling and Long-Term Monitoring for Hydropower Projects in the Himalayan Region, IFC, 2021. Available at: https://www.ifc.org/content/dam/ifc/doc/mgrt/ifc-trishuli-assessment-tool-field-manual-2021.pdf
- **IMPERIA, 2015:** Guidelines for the systematic impact significance assessment – The ARVI approach IMPERIA Project Report, December 31, 2015
- **EMEP/EEA, 2019:** European Monitoring and Evaluation Programme / European Environment Agency (EMEP/EEA), 2019: EMEP/EEA air pollutant emission inventory guidebook 2019. Luxembourg: Publications Office of the European Union.
- **EU, 2017:** Environmental Impact Assessment of Projects - Guidance on Scoping, European Union, 2017
- **Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016):** Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. Geoscientific Model Development, 9(5), 1937–1958. https://doi.org/10.5194/gmd-9-1937-2016
- **Garee, H. K., Chen, X., Bao, A., Wang, Y., & Meng, F. (2017):** Hydrological modeling of the Upper Indus Basin: A case study from a high-altitude glacierized catchment. Water, 9(1), 17. https://doi.org/10.3390/w9010017
- **Gurung, D. R., Khanal, N. R., Bajracharya, S. R., Tsering, K., Joshi, S., Tshering, P., Chhetri, L. K., Lotay, Y., & Penjor, T. (2017):** Lemthang Tsho glacial lake outburst flood (GLOF) in Bhutan: Cause and impact. Geoenvironmental Disasters, 4(17). https://doi.org/10.1186/s40677-017-0080-2
- **Gyeltshen, S., Adhikari, R., Budha, P. B., Thapa, G., Subedi, K. K., & Singh, B. K. (2021):** Remote sensing and GIS-based soil loss estimation for Bhutan using RUSLE model. Geocarto International. https://doi.org/10.1080/10106049.2021.1936210
- **Ives, J. D., Shrestha, R. B., & Mool, P. K. (2010):** Formation of glacial lakes in the Hindu Kush-Himalayas and GLOF risk assessment. International Centre for Integrated Mountain Development (ICIMOD).
- **Jigme Khesar Strict Nature Reserve. (2024):** Environmental and Social Management Plan for Jigme Khesar Strict Nature Reserve (January 2023 - June 2024). Bhutan For Life.
- **Kadiyala, A., Kommalapati, R., & Huque, Z. (2016).** Evaluation of the Life Cycle Greenhouse Gas Emissions from Hydroelectricity Generation Systems. Sustainability, 8(6), 539. https://doi.org/10.3390/su8060539
- **Key Biodiversity Areas Partnership (2026) Key Biodiversity Areas factsheet: Ada lake / Puna Tsangchu**. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal

Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society. Downloaded from https://keybiodiversityareas.org/ on Apr 1, 2026.

- **Key Biodiversity Areas Partnership (2026) Key Biodiversity Areas factsheet: Chele La**. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society. Downloaded from https://keybiodiversityareas.org/ on Apr 1, 2026.
- **Key Biodiversity Areas Partnership (2026) Key Biodiversity Areas factsheet: Paro wetlands**. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society. Downloaded from https://keybiodiversityareas.org/ on Apr 1, 2026.
- **Key Biodiversity Areas Partnership (2026) Key Biodiversity Areas factsheet: Samtse**. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe
- **Key Biodiversity Areas Partnership (2026) Key Biodiversity Areas factsheet: Thimphu wetlands**. Extracted from the World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society. Downloaded from https://keybiodiversityareas.org/ on Apr 1, 2026.
- **Kleynhans, Cj., 1996:** A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). Journal of Aquatic Ecosystem Health. 5. 41-54. 10.1007/BF00691728. Available at: https://www.researchgate.net/publication/226742006_A_qualitative_procedure_for_the_assessment_of_the_habitat_integrity_status_of_the_Luvuvhu_River_Limpopo_system_South_Africa
- Komori, J., Koike, T., Yamanokuchi, T., & Tshering, P. (2012). Glacial lake outburst events in the Bhutan Himalayas. Global Environmental Research, 16(2012), 59–70.
- **Mann, H. B. (1945):** Nonparametric tests against trend. Econometrica, 13(3), 245–259
- **Marahatta, S., Devkota, L. P., & Aryal, D. (2021):** Application of SWAT in hydrological simulation of complex mountainous river basin (Part I: Model development). Water, 13(11), 1546. https://doi.org/10.3390/w13111546
- **Mendelow, A. L. (1991)**: Environmental Scanning: The Impact of the Stakeholder Concept. Proceedings From the Second International Conference on Information Systems 407-418. Cambridge, MA. Available at: https://www.semanticscholar.org/paper/Environmental-Scanning-The-Impact-of-the-Concept-Mendelow/7b361652157989c77ed442dd387ec9b1a9b99632
- **Millennium Ecosystem Assessment, 2005:** Ecosystems and human well-being: Policy responses. Washington, DC: Island Press.

- **Ministry of Energy and Natural Resources. (2025):** National energy policy 2025. Royal Government of Bhutan.
- **Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007):** Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE, 50(3), 885–900
- **NAMGAY, T. K. (2023):** Glacier variation (terminus & surface area) in Bhutan Himalaya from 1990–2020 as deduced from three benchmark glaciers and comparative analysis across the Himalaya. Bhutan Hydro-Met Journal, II, 1–21. NCHM.
- **NEC, 2021:** Bhutan Biodiversity User List, National Environment Commission, Royal Government of Bhutan, Thimpu, 2021
- **National Environment Commission. (2020):** Climate Change Policy of the Kingdom of Bhutan. Royal Government of Bhutan.
- **National Environment Commission (NEC), 2020 :** Environmental Standards 2020. Thimphu: Royal Government of Bhutan.
- **NCHM. National Center for Hydrology and Meteorology. (2020)**: Detailed assessment report on GLOF hazard from Thorthormi glacial lake and associated glaciers (Field season: September–October 2019). Royal Government of Bhutan.
- **Neitsch, S. L., Arnold, J. G., Kiniry, J. R., & Williams, J. R. (2011):** Soil and Water Assessment Tool: Theoretical Documentation, Version 2009. Texas Water Resources Institute, Technical Report No. 406.
- **Occupational Safety and Health Administration (OSHA), 2022:** OSHA Technical Manual (OTM) U.S. Department of Labor. Retrieved from https://www.osha.gov/otm/section-3-health-hazards/chapter-5
- **Pandey, V. P., Dhaubanjar, S., Bharati, L., & Thapa, B. R. (2020):** Spatio-temporal distribution of water availability in Karnali–Mohana Basin, Western Nepal: Hydrological model development using multi-site calibration approach (Part A). Journal of Hydrology: Regional Studies, 29, 100690. https://doi.org/10.1016/j.ejrh.2020.100690
- **Rainforest Trust, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society on Apr 1, 2026**. Downloaded from https://keybiodiversityareas.org/
- **Royal Government of Bhutan. (2025):** Third nationally determined contribution (provisional). Ministry of Energy and Natural Resources, Department of Environment and Climate Change.
- **Sattar, A., Haritashya, U. K., Kargel, J. S., Leonard, G. J., Shugar, D. H., & Chase, D. V. (2021)**:Modeling lake outburst and downstream hazard assessment of the Lower Barun Glacial Lake, Nepal Himalaya. Journal of Hydrology, 598, 126208. https://doi.org/10.1016/j.jhydrol.2021.126208
- **Shannon & Weaver, 1949:** Shannon, C. ., & Weaver, W. (1949). The Mathematical Theory of Communication. University of Illinois Press, Urba.
- **Shrestha, A. B. (2008):** Resource manual on flash flood risk management: Module 2 – Non-structural measures. International Centre for Integrated Mountain Development (ICIMOD).
- **Shrestha, D., Basnyat, D. B., Gyawali, J., Creed, M. J., Sinclair, H. D., Golding, B., Muthusamy, M., Shrestha, S., Watson, C. S., Subedi, D. L., & Haiju, R. (2023):** Rainfall extremes under future climate change with implications for urban flood risk in Kathmandu, Nepal. International Journal of Disaster Risk Reduction, 97, 103997. https://doi.org/10.1016/j.ijdrr.2023.103997

- **Shrestha, F., Steiner, J. F., Shrestha, R., Dhungel, Y., Joshi, S. P., Inglis, S., Ashraf, A., Wali, S., Walizada, K. M., & Zhang, T. (2023):** A comprehensive and version-controlled database of glacial lake outburst floods in High Mountain Asia. Earth System Science Data, 15, 3941–3961. https://doi.org/10.5194/essd-15-3941-2023
- **Thrasher, B., Wang, W., Michaelis, A., Melton, F., Lee, T., & Nemani, R. (2022):** NASA Global Daily Downscaled Projections CMIP6. Scientific Data, 9, 262. https://doi.org/10.1038/s41597-022-01393-4
- **Thrasher et al., 2022:** NASA Global Daily Downscaled Projections, CMIP6, Springer Nature, 02 June 2022
- **United States Environmental Protection Agency (U.S. EPA), n.d.:** Criteria Air Pollutants. Retrieved from https://www.epa.gov/criteria-air-pollutants
- **Veh, G., Lützow, N., Kharlamova, V., Petrakov, D., Hugonnet, R., & Korup, O. (2022)**: Trends, breaks, and biases in the frequency of reported glacier lake outburst floods. Earth's Future, 10, e2021EF002426. https://doi.org/10.1029/2021EF002426
- **World Health Organization (WHO), 2018:** Environmental Noise Guidelines for the European Region. Copenhagen: WHO Regional Office for Europe.
- **World Health Organization (WHO), 2021:** WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization.
- **World Health Organization (WHO), 2022:** Guidelines for drinking-water quality (4th ed. incorporating the first and second addenda). Geneva: World Health Organization.
- **WWF Bhutan. (n.d.). Jigme Dorji National Park. Retrieved April 1, 2026**, from https://www.wwfbhutan.org.bt/b2c2_areas/jdnp/

Annexes

Annexes 1: CV of the ESIA team attached with final ESIA report

Annexes 2: Policy and Legal Framework is attached

Annexes 3: Maps and Figure- along with report

Annexes 4: Reports for Physical environment survey

Annexes 5: Report on Biodiversity Surveys

Annexes 6: Report on socioeconomic survey

Annexes 7: Critical Habitat Assessment

Annexes 8: E-flow Report

Annexes 9: Draft Resettlement Plan

Annexes 10: Stakeholder Engagement Plan

Annexes 11: Gender and Vulnerability Assessment and Action Plan

Annexe 12: Biodiversity Action Plan

Annexes 13: eDNA Report

Summary tables of surveyed biodiversity elements

Notes:

- S1 = Pre-monsoon/dry/spring (March 2025)
- S2 = Monsoon/wet/summer (Aug–Sep 2025)
- S3 = Post-monsoon/autumn (Nov–Dec 2025).
- Species occurrence reflects seasonal hydrological variability and detectability; absence in each season does not necessarily indicate true absence

Table 137: Fish Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status

S.N	Scientific Name	Common Name	IUCN Status	Season of Record
1	*Schizothorax richardsonii*	Snow Trout	VU	S1, S2, S3
2	*Salmo trutta*	Brown Trout	LC	S1, S2, S3
3	*Neolissochilus hexagonolepis*	Copper Mahseer	NT	S2, S3

S.N	Scientific Name	Common Name	IUCN Status	Season of Record
4	*Psilorhynchus arunachalensis*		DD	S2
5	*Psilorhynchus balitora*		LC	S2, S3
6	*Pseudochinensis sulcata*		LC	S2, S3
7	*Opsarius barna*	Barna Fish	LC	S2, S3
8	*Opsarius vagra*		LC	S2, S3
9	*Opsarius bendelisis*		LC	S2
10	*Xenentodon cancila*		LC	S2
11	*Channa quinquefasciata*		NE	S2
12	*Diano dangila*		LC	S2
13	*Devario aequipinnatus*		LC	S2, S3
14	*Tor putitora*	Golden Mahseer	EN	S2
15	*Parachiloglanis hodgarti*	Bathbalanga	LC	S2, S3
16	*Paracanthocobitis abutwebi*		NE	S2
17	*Schistura* sp.	Gadera	LC	S2
18	*Garra annandalei*		LC	S2, S3
19	*Garra birostris*		NE	S2, S3
20	*Garra* sp. 1			S2
21	*Garra* sp. 2			S2
22	*Badis badis*		LC	S2
23	*Pethia conchonius*		LC	S2
24	*Mystus* sp.	Jantura	LC	S2
25	*Semiplotus semiplotus*		VU	S2, S3
26	*Aborichthys elongatus*		LC	S2
27	*Glyptothorax* sp.		LC	S2
28	*Amblyceps apangi*		LC	S2
29	*Batasio merianiensis*		DD	S2

Table 138: Dominant Tree Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status

SN	Scientific Name	English Name	Local Name	Season of Record
1	*Acer campbellii*	Himalayan Maple		S1, S2, S3
2	*Actinodaphne obovata*	Laurel		S1, S2, S3
3	*Alnus nepalensis*	Himalayan Alder	Utis	S1, S2, S3
4	*Benthamedia capitata*	Himalayan Dogwood		S1, S2, S3
5	*Betula alnoides*	Himalayan Birch		S1, S2, S3
6	*Brassiopsis hainla*	Aralia Tree		S1, S2, S3
7	*Carpinus viminea*	Himalayan Hornbeam		S1, S2, S3
8	*Castanopsis spp.*	Chinquapin	Katus	S2, S3
9	*Celtis tetranda*	Himalayan Nettle Tree		S1, S2, S3
10	*Cinnamomum glanduliferum*	Wild Cinnamon		S1, S2, S3
11	*Corylus ferox*	Himalayan Hazel		S1, S2, S3
12	*Dodecadenia grandiflora*	Evergreen Laurel		S1, S2, S3
13	*Eurya acuminata*	Eurya		S1, S2, S3
14	*Lithocarpus elegans*	Stone Oak		S2, S3
15	*Lithocarpus fenestratus*	Stone Oak		S1, S2, S3
16	*Lyonia ovalifolia*	Fetterbush		S1, S2, S3
17	*Michelia doltsopa*	Magnolia		S1, S2, S3
18	*Macaranga pustulata*	Blistery Macaranga		S1
19	*Persea spp.*	Wild Avocado		S1, S2, S3
20	*Picea spinulosa*	Himalayan Spruce		S1, S2, S3
21	*Pieris formosa*	Andromeda Tree		S1, S2, S3
22	*Pinus wallichiana*	Blue Pine	Gobre Salla	S1, S2, S3
23	*Populus ciliata*	Himalayan Poplar		S1, S2, S3
24	*Prunus carmesina*	Wild Cherry		S1, S2, S3
25	*Prunus nepalensis*	Nepal Cherry		S1, S2, S3
26	*Quercus glauca*	Japanese Blue Oak		S1, S2, S3
27	*Quercus griffithii*	Oak		S1, S2, S3
28	*Quercus lamellosa*	Brown Oak		S2, S3
29	*Quercus lanata*	Woolly-leaved Oak		S1, S2, S3

SN	Scientific Name	English Name	Local Name	Season of Record
30	*Quercus oxyodon*	Sharp-toothed Oak		S1, S2, S3
31	*Quercus semecarpifolia*	Himalayan Oak		S1, S2, S3
32	*Rhododendron arboreum*	Tree Rhododendron	Lali Gurans	S1, S2, S3
33	*Rhododendron griffithianum*	Rhododendron		S1, S2, S3
34	*Rhus spp.*	Sumac		S1, S2, S3
35	*Salix wallichiana*	Himalayan Willow		S1, S2, S3
36	*Schoepfia jasminodora*	Schoepfia		S1, S2, S3
37	*Symplocos paniculata*	Symplocos		S1, S2, S3
38	*Symplocos racemosa*	Symplocos		S1, S2, S3
39	*Symplocos ramosissima*	Symplocos		S1, S2, S3
40	*Symplocos sumuntia*	Symplocos		S1, S2, S3
41	*Tetradium fraxinifolium*	Evodia Tree		S2, S3
42	*Toricellia tiliifolia*	Toricellia		S1, S2, S3
43	*Tsuga dumosa*	Himalayan Hemlock		S1, S2, S3
44	*Viburnum cylindricum*	Viburnum		S1, S2, S3
45	*Zanthoxylum armatum*	Nepal Pepper	Timur	S1, S2, S3

Table 139: Mammal Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status

S.N.	Species	IUCN Status	Type of Record	Habitat Observed	Season of Record
1	Wild Pig (*Sus scrofa*)	LC	Tracks, sightings, signs	Forest slopes, disturbed forest edges	S1, S2, S3
2	Barking Deer (*Muntiacus muntjak*)	LC	Tracks and sightings	Broadleaved forest and riverine areas	S1, S2, S3
3	Himalayan Black Bear (*Ursus thibetanus*)	VU	Signs, livestock predation report	Forest near settlements	S1, S2, S3
4	Assamese Macaque (*Macaca assamensis*)	NT	Direct sightings	Forest canopy and forest edges	S2, S3
5	Sambar (*Rusa unicolor*)	VU	Tracks and signs	Dense forest habitats	S1, S2, S3
6	Himalayan Goral (*Naemorhedus goral*)	NT	Direct sightings	Rocky slopes and cliffs	S2, S3
7	Yellow-throated Marten (*Martes flavigula*)	LC	Direct observation	Mixed forest areas	S2, S3
8	Dhole (*Cuon alpinus*)	EN	Signs and tracks	Forest habitats	S2, S3
9	Himalayan Grey Langur (*Semnopithecus schistaceus*)	LC	Direct sightings	Forest canopy and open forest	S2, S3
10	Leopard Cat (*Prionailurus bengalensis*)	LC	Signs and sightings	Forest edge and dense vegetation	S2, S3

Note:

Mammal records are based on direct sightings and indirect evidence (tracks, scats, and local information)

Table 140: Bird Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status

SN	Common Name	Scientific Name	IUCN Status	FNCA Bhutan 2023	Season of Record
1	Alpine Thrush	*Zoothera mollissima*	LC	Nil	S3
2	Ashy Drongo	*Dicrurus leucophaeus*	LC	Nil	S1, S2
3	Asian Barred Owlet	Glaucidium cuculoides	LC	Schedule III	S1
4	Ashy-throated Warbler	*Phylloscopus maculipennis*	LC	Nil	S3
5	Bay Woodpecker	*Blythipicus pyrrhotis*	LC	Nil	S3
6	Black Bulbul	*Hypsipetes leucocephalus*	LC	Nil	S1, S2, S3
7	Black-headed shrike Babbler	*Pteruthius rufiventer*	LC	Nil	S1
8	Black-throated Tit	*Aegithalos concinnus*	LC	Nil	S1, S2, S3
9	Blue Whistling Thrush	*Myophonus caeruleus*	LC	Nil	S1, S2, S3
10	Black-winged Cuckooshrike	*Coracina melaschistos*	LC	Nil	S1
11	Blue-fronted Redstart	*Phoenicurus frontalis*	LC	Nil	S3
12	Blyth's Leaf Warbler	*Phylloscopus reguloides*	LC	Schedule III	S1, S2, S3
13	Brown Dipper	*Cinclus pallasii*	LC	Nil	S1, S2, S3
14	Brown Parrotbill	*Cholornis unicolor*	LC	Nil	S1, S2, S3
15	Brownish-flanked Bush Warbler	*Cettia pallidipe*	LC	Nil	S1
16	Buff-barred Warbler	*Phylloscopus* pulcher	LC	Nil	S1
17	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	LC	Nil	S3
18	Chestnut-crowned Laughingthrush	*Garrulax erythrocephalus*	LC	Nil	S1, S3
19	Crested Kingfisher	*Megaceryle lugubris*	LC	Nil	S3
20	Crimson sunbird	*Aethopyga siparaja*	LC	Nil	S1

SN	Common Name	Scientific Name	IUCN Status	FNCA Bhutan 2023	Season of Record
21	Common Green Magpie	*Cissa chinensis*	LC	Nil	S1
22	Common Hoopoe	*Upupa epops*	LC	Nil	S1, S2
23	Common Stonechat	*Saxicola torquata*	LC	Nil	S1, S2
24	Darjeeling Woodpecker	*Dendrocopos darjellensis*	LC	Nil	S1, S2, S3
25	Eurasian Cuckoo	*Cuculus canorus*	LC	Nil	S1
26	Eurasian Wren	*Troglodytes troglodytes*	LC	Nil	S3
27	Eurasian Jay	*Garrulus glandarius*	LC	Nil	S1, S2, S3
28	Great Cormorant	*Phalacrocorax carbo*	LC	Nil	S3
29	Great Barbet	*Psilopogon virens*	LC	Nil	S1, S2, S3
30	Grey Bushchat	*Saxicola ferreus*	LC	Nil	S1
31	Grey-backed Shrike	*Lanius tephronotus*	LC	Nil	S1, S2
32	Grey-winged Blackbird	*Turdus boulboul*	LC	Nil	S1, S2
33	Golden-throated Barbet	*Psilopogon franklinii*	LC	Nil	S1
34	Green-backed Tit	*Parus monticolus*	LC	Nil	S1, S2, S3
35	Green-tailed Sunbird	*Aethopyga nipalensis*	LC	Nil	S1, S2
36	Grey-headed Canary Fycatcher	*Culicicapa ceylonensis*	LC	Nil	S1, S2
37	Grey-hooded Warbler	*Phylloscopus xanthoschistos*	LC	Nil	S3
38	Grey-sided Laughingthrush	*Garrulax caerulatus*	LC	Nil	S3
39	Himalayan Bluetail	*Tarsiger rufilatus*	LC	Nil	S3
40	Hill Partridge	*Arborophila torqueola*	LC	Schedule III	S1, S2, S3
41	Hodgson's Redstart	*Phoenicurus ochruros*	LC	Schedule I	S1
42	House Crow	*Corvus splendens*	LC	Nil	S1, S2
43	Hume's Warbler	*Phylloscopus humei*	LC	Nil	S1, S2
44	Indian Cuckoo	*Cuculus micropterus*	LC	Schedule III	S1, S2

SN	Common Name	Scientific Name	IUCN Status	FNCA Bhutan 2023	Season of Record
45	Indian Nuthatch	*Sitta castanea*	LC	Nil	S1
46	Kalij Pheasant	*Lophura leucomelanos*	LC	Schedule III	S1, S2
47	Large-billed Crow	*Corvus macrorhynchos*	LC	Schedule III	S1, S2
48	Large Hawk Cuckoo	*Hierococcyx sparverioides*	LC	Schedule III	S1
49	Lesser Yellownape	*Picus chlorolophus*	LC	Nil	S1
50	Lemon-rumped Warbler	*Phylloscopus chloronotus*	LC	Nil	S2
51	Long-tailed Minivet	*Pericrocotus ethologus*	LC	Nil	S1, S2
52	Maroon Oriole	*Oriolus traillii*	LC	Nil	S1, S2
53	Mountain Hawk Eagle	*Nisaetus nipalensis*	LC	Nil	S1
54	Mrs Gould's Sunbird	*Aethopyga gouldiae*	LC	Nil	S1, S2
55	Nepal Fulvetta	*Alcippe nipalensis*	LC	Nil	S1, S2
56	Olive-backed Pipit	*Anthus hodgsoni*	LC	Nil	S1
57	Oriental Turtle Dove	*Streptopelia orientalis*	LC	Nil	S1, S2
58	Oriental White-eye	Zosterops palpebrosus	LC	Nil	S1, S2
59	Pied Bushchat	*Saxicola caprata*	LC	Nil	S1
60	Plumbeous Water Redstart	*Phoenicurus fuliginosus*	LC	Nil	S1, S2
61	Red-billed Chough	*Pyrrhocorax pyrrhocorax*	LC	Schedule III	S1
62	Red-faced Liocichla	*Liocichla phoenicea*	LC	Nil	S1
63	Red-tailed Minla	*Minla ignotincta*	LC	Nil	S1, S2
64	Red-headed Bullfinch	*Pyrrhula erythrocephala*	LC	Nil	S2, S3
65	Rusty-fronted Barwing	*Actinodura egertoni*	LC	Nil	S2, S3
66	Red-vented Bulbul	*Pycnonotus cafer*	LC	Nil	S1
67	Rufous-bellied Woodpecker	*Dendrocopos hyperythrus*	LC	Nil	S1, S2
68	Rufous Sibia	*Heterophasia capistrata*	LC	Nil	S1, S2

SN	Common Name	Scientific Name	IUCN Status	FNCA Bhutan 2023	Season of Record
69	Rufous-breasted Accentor	*Prunella strophiata*	LC	Nil	S2, S3
70	Rufous-gorgeted Flycatcher	*Ficedula strophiata*	LC	Nil	S2, S3
71	Rufous -vented Yuhina	*Yuhina occipitalis*	LC	Nil	S1, S2
72	Scaly-breasted Wren-Babbler	*Pnoepyga albiventer*	LC	Nil	S2, S3
73	Scarlet Minivet	*Pericrocotus flammeus*	LC	Nil	S1, S2
74	Short-billed Minivet	*Pericrocotus brevirostris*	LC	Nil	S1
75	Sikkim Treecreeper	*Certhia discolor*	LC	Nil	S1, S2
76	Small Niltava	*Niltava macgrigoriae*	LC	Nil	S2
77	Spotted Nutcracker	*Nucifraga caryocatactes*	LC	Nil	S1, S2
78	Spotted Laughingthrush	*Lanthocincla ocellata*	LC	Nil	S1, S2
79	Spotted Forktail	*Enicurus maculatus*	LC	Nil	S2
80	Streak-breasted Scimitar Babbler	*Pomatorhinus ruficollis*	LC	Nil	S1, S2
81	Striated Bulbul	*Pycnonotus striatus*	LC	Nil	S1
82	Striated Laughingthrush	*Grammatoptila striata*	LC	Nil	S1, S2
83	Stripe-throated Yuhina	*Yuhina gularis*	LC	Nil	S1, S2
84	Verditer Flycatcher	*Eumyias thalassina*	LC	Nil	S1, S2
85	White Wagtail	*Motacilla alba*	LC	Nil	S2
86	White-spectacled Warbler	*Seicercus affinis*	LC	Nil	S1, S2
87	White-tailed Nuthatch	*Sitta himalayensis*	LC	Nil	S1, S2
88	White-throated Fantail	*Rhipidura albicollis*	LC	Nil	S2
89	White-throated Laughingthrush	*Garrulax albogularis*	LC	Nil	S1, S2
90	White-capped Water Redstart	*Phoenicurus leucocephalus*	LC	Nil	S1, S2
91	Whiskered Yuhina	*Yuhina flavicollis*	LC	Nil	S1, S2

SN	Common Name	Scientific Name	IUCN Status	FNCA Bhutan 2023	Season of Record
92	Yellow-billed Blue Magpie	*Urocissa flavirostris*	LC	Nil	S1, S2
93	Yellow-bellied Fantail	*Chelidorhynx hypoxanthus*	LC	Nil	S1
94	Yellow-browed Fulvetta	*Alcippe cinereiceps*	LC	Nil	S1
95	Yellow-browed Warbler	*Phylloscopus inornatus*	LC	Nil	S1
96	Yellow-vented Warbler	*Phylloscopus cantator*	LC	Nil	S1
97	Golden Bush Robin	*Tarsiger chrysaeus*	LC	Nil	S2, S3

Table 141: Herpetofauna Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status (top of form)

SN	Scientific Name	Common Name	Family	IUCN	Season of Record
Amphibians					
1	*Duttaphrynus melanostictus*	Asian Common Toad	Bufonidae	LC	S2, S3
2	*Fejervarya limnocharis*	Paddy Field Frog	Dicroglossidae	LC	S2
3	*Hoplobatrachus tigerinus*	Indian Bullfrog	Dicroglossidae	LC	S2, S3
Reptiles (Snakes)					
4	*Ptyas mucosa*	Oriental Rat Snake	Colubridae	LC	S1, S3
5	*Boiga trigonata*	Common Cat Snake	Colubridae	LC	S3
6	*Coelognathus helena*	Trinket Snake	Colubridae	LC	S1
7	*Ahaetulla nasuta*	Green Vine Snake	Colubridae	LC	S3
8	*Rhabdophis subminiatus*	Red-necked Keelback	Colubridae	LC	S2
9	*Amphiesma stolatum*	Buff-striped Keelback	Colubridae	LC	S2, S3
10	*Xenochrophis piscator*	Checkered Keelback	Colubridae	LC	S2
11	*Oligodon arnensis*	Kukri Snake	Colubridae	LC	S1
12	*Lycodon aulicus*	Common Wolf Snake	Colubridae	LC	S3

SN	Scientific Name	Common Name	Family	IUCN	Season of Record
13	*Elaphe radiata*	Radiated Rat Snake	Colubridae	LC	S1
14	*Dendrelaphis tristis*	Bronze-back Tree Snake	Colubridae	LC	S3
15	*Naja naja*	Indian Cobra	Elapidae	LC	S1, S2
16	*Bungarus caeruleus*	Common Krait	Elapidae	LC	S1
17	*Python bivittatus*	Burmese Python	Pythonidae	VU	S3
18	*Trimeresurus albolabris*	White-lipped Pit Viper	Viperidae	LC	S2, S3
19	*Trimeresurus erythrurus*	Himalayan Pit Viper	Viperidae	LC	S3
20	*Daboia russelii*	Russell's Viper	Viperidae	LC	S1
Reptiles (Lizards)					
21	*Calotes versicolor*	Oriental Garden Lizard	Agamidae	LC	S1, S2, S3
22	*Japalura variegata*	Himalayan Agamid	Agamidae	LC	S3
23	*Hemidactylus frenatus*	Common House Gecko	Gekkonidae	LC	S1, S2, S3
24	*Hemidactylus brookii*	Brook's Gecko	Gekkonidae	LC	S1, S2, S3
25	*Eutropis carinata*	Common Skink	Scincidae	LC	S1, S3
26	*Eutropis macularia*	Bronze Grass Skink	Scincidae	LC	S2
27	*Sphenomorphus indicus*	Forest Skink	Scincidae	LC	S3
Reptiles (Turtle)					
28	*Indotestudo elongata*	Elongated Tortoise	Testudinidae	EN	S3

Table 142: Invasive Plant Species Recorded During the Surveys, Showing Genus, Species, and their IUCN Red List Conservation Status (top of form)

SN	Scientific Name	Common Name	Origin	Habitat	Risk Level	Season of Record
1	*Ageratina adenophora*	Crofton Weed	Invasive	Roadside, slopes	High	S1, S2, S3
2	*Chromolaena odorata*	Siam Weed	Invasive	Open disturbed land	High	S2

SN	Scientific Name	Common Name	Origin	Habitat	Risk Level	Season of Record
3	*Lantana camara*	Lantana	Invasive	Forest edge	High	S1, S3
4	*Mikania micrantha*	Mile-a-minute	Invasive	Moist forest, riparian	High	S3
5	*Parthenium hysterophorus*	Congress Weed	Invasive	Roadsides, settlements	High	S1, S2
6	*Bidens pilosa*	Blackjack	Invasive	Agricultural edges	Moderate	S1
7	*Xanthium strumarium*	Cocklebur	Invasive	Riverbanks	Moderate	S2, S3
8	*Eupatorium spp.*	Eupatorium	Invasive	Disturbed forest	Moderate–High	S2
9	*Ageratum conyzoides*	Billygoat Weed	Invasive	Open disturbed land	Moderate	S1
10	*Oxalis latifolia*	Wood Sorrel	Invasive	Moist disturbed soil	Moderate	S1
11	*Amaranthus spinosus*	Spiny Amaranth	Exotic	Open land	Low–Moderate	S1, S2, S3
12	*Cassia tora*	Sickle Senna	Exotic	Roadside	Low	S1
13	*Datura stramonium*	Jimson Weed	Exotic	Disturbed soil	Low	S1
14	*Solanum nigrum*	Black Nightshade	Exotic	Agricultural margins	Low	S2
15	*Solanum torvum*	Turkey Berry	Exotic	Shrubland	Low–Moderate	S3
16	*Ipomoea purpurea*	Morning Glory	Exotic	Disturbed vegetation	Moderate	S1
17	*Ipomoea carnea*	Pink Morning Glory	Invasive	Moist areas	High	S2, S3
18	*Ricinus communis*	Castor Plant	Exotic	Waste land	Low	S1
19	*Argemone mexicana*	Mexican Poppy	Exotic	Dry disturbed areas	Low	S1
20	*Cynodon dactylon*	Bermuda Grass	Invasive	Open land	Moderate	S1, S2
21	*Imperata cylindrica*	Cogon Grass	Invasive	Degraded slopes	High	S1, S2

SN	Scientific Name	Common Name	Origin	Habitat	Risk Level	Season of Record
22	*Pennisetum purpureum*	Elephant Grass	Exotic/Invasive	Disturbed land	Moderate	S2
23	*Saccharum spontaneum*	Wild Sugarcane	Invasive	Riverbanks	Moderate	S2, S3
24	*Setaria spp.*	Foxtail Grass	Invasive	Open land	Low–Moderate	S1
25	*Commelina benghalensis*	Dayflower	Invasive	Moist soil	Moderate	S2, S3