Environmental Impact Assessment (Draft)

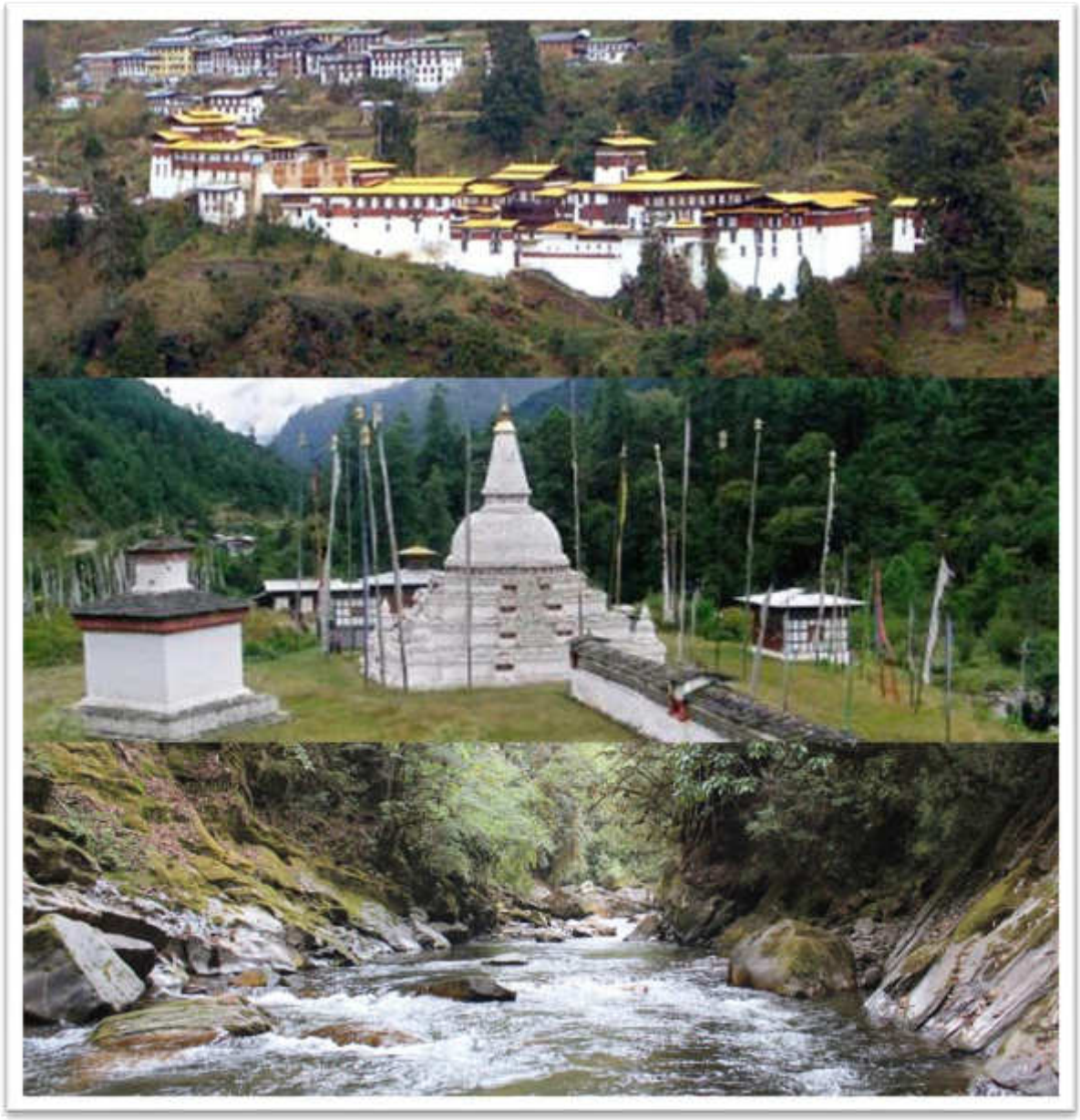
August 2014

BHU: Green Power Development Project II

(Part A: Hydropower Plant Component)

Main Report

Prepared by Druk Green Power Corporation Limited and Tangsibji Hydro Energy Limited for the Asian Development Bank



NIKACHHU HYDROPOWER PROJECT, BHUTAN (118 MW)

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT REPORT (ESIA) - 2014

VOLUME IV: MAIN REPORT (PART 1)

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Preamble

The Nikachhu Hydropower Project Environmental and Social Impact Assessment (ESIA) was originally prepared in 2012 by BHUCORE. This current version of the ESIA is a revision of the September 2012 draft, and reflects additional field surveys, site visits, consultations with stakeholders in the Trongsa area and Thimphu, and various briefing sessions with stakeholders and regulators (including an information session and initial review by the National Environmental Commission). It also reflects a detailed study of the project components and impacts at the Dagachhu Hydropower Project site, as there are many similarities between the two projects. It has been prepared by two PricewaterhouseCoopers (PWC India) consultants, within the overall ADB technical assistance being provided to the Druk Green Power Corporation Limited and Tangsibji Hydro Energy Limited (THyE).

The structure and orientation of this version of the ESIA have been adjusted to create a stronger focus on environmental and social attributes in the project area that are most vulnerable to development activities and more analysis of the possible impacts of the proposed project. There is, therefore, less listing and enumeration of features that are not likely to be affected by the project, either due to lack of proximity, strong resilience, or the fact that only a very small proportion of that feature is taken up in the "footprint" of the project (much of this listed information has been put in the annexes). This helps to sharpen the focus on required environmental and social management measures, ensuring that they are responsive and practical. This ESIA reflects the requirements of the Royal Government of Bhutan, while also being compliant with the Environmental Safeguard policies of ADB, so that this one document can meet the requirements for approvals in both Bhutan and at ADB.

The Nikachhu Hydropower Project ESIA comprises three parts: Part 1 (the environmental and social baseline data, impact assessment, and mitigation measures); Part 2 (the Environmental Management Plan); and, Part 3 (the Resettlement Plan). This report structure reflects the requirements of the Royal Government of Bhutan (submissions to ADB may comprise smaller sets of documents).

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ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
BAP	Biodiversity Action Plan
BC	Biological Corridor
BHUCORE	Bhutan Consultants & Research
CA	Competent Authority
CDM	Clean Development Mechanism
CITIES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
Db	decibel
DGM	Department of Geology and Mines
DGPCL	Druk Green Power Corporation Limited
DHPP	Dagachhu Hydropower Project
DoF	Department of Forest
DoR	Department of Roads
EA	Environmental Assessment
EC	Environmental Clearance
EFP	Environmental Focal Person
EMP	Environment Management Plan
EPA	Environment Protection Agency
ESIA	Environmental and Social Impact Assessment
FNCA	Forest and Nature Conservation Act
GI	Galvanized Iron
GIS	Geographical Information System
GLOF	Glacial Lake Outburst Flooding
GPS	Global Positioning System
HH	Households
HRT	Head Race Tunnel
HSU	Hertz Smoke Unit
IIT	Indian Institute of Technology
IPCC	Inter-Governmental Panel on Climate Change
JE	Junior Engineer
JSWNP	Jigme Singye Wangchuck National Park
LPG	Petrol and Liquid Petroleum Gas
MAT	Main Access Tunnel
MHEP	Mangdechhu Hydro-Electric Project
MoAF	Ministry of Agriculture & Forest

MT	Metric Tons
NCD	Nature Conservation Division
NECS	National Environment Commission Secretariat
NHPP	Nikachhu Hydropower Project
NOC	No Objection Certificate
OHS	Occupational Health and Safety
PA	Project Authority
PFS	Pre-Feasibility Study
PH	Power House at Norbuodi
PM	Particulate Matter
POL	Petroleum Oil Lubricant
PSMP	Power System Master Plan
PWC	PriceWaterhouseCoopers
RS	Resettlement Plan
SPS	Safeguard Policy Statement
TA	Technical Assistance
TERI	Energy and Research Institute
TGC	Thimphu Gneissic Complex
ToR	Terms of Reference
TRT	Tail Race Tunnel
UNCCD	United Nations Convention to Combat Desertification

EXECUTIVE SUMMARY

Introduction

Druk Green Power Corporation Limited (DGPCL) is mandated to look after the existing power generating facilities and development of new hydropower projects in Bhutan. Tangsibji Hydro Energy Limited (THyE), a special purpose vehicle which is a 100% subsidiary compny of DGPCL incorporated on April 25, 2014 with the Managinf Director shall be implementing the 118 MW Nikachhu Hydropower Project (NHPP), to be located in Trongsa District. This run-of-river project will draw from the Nikachhu and discharge its tailrace water above the dam of the Mangdechhu HPP, adding power potential to that project. The Nikachhu project will be constructed over a 4-year period and could be operational by 2018. As specified by National Environment Commission Regulations and ADB safeguard standards, an Environmental and Social Impact Assessment (ESIA) is required. This document meets those requirements, and includes the impact assessment (Part 1), an Environmental Management Plan (EMP; Part 2), and a Resettlement Plan (Part 3). The original ESIA was prepared by Bhutan Consultants & Research (BHUCORE) in 2012. It was subsequently revised by PWC consultants, based on additional field data and consultations undertaken in 2013.

This version of the ESIA reflects all required revisions noted by the formal NEC review and the ADB internal review.

Project Alternatives

In the Pre-Feasibility Study (PFS), two alternatives were studied, considering the dam site at D1, located about 7.5 km downstream of Chendebji Chorten, and the powerhouse at Tangsibji. The Alternative 1 was aligned along the left bank of the Nikachhu and Alternative 2 was on the right bank. Considering the techno-economic and socio-environmental assessment, the project Alternative 1 along the left bank of the Nikachhu was found to be more feasible with an installed capacity of 210 MW. The ESIA studies for this alternative was prepared and submitted to NEC (vide letter no. DGPC/PD/Nikachhu/2011/1316 on 22nd April, 2011) for review and approval. Further, 6 alternatives with different configurations of the dam and powerhouse sites were studied as part of the PFS update, considering techno-economic feasibility and socio-environmental aspects. Subsequently, the Druk Green's Board, in its 30th Meeting held in October 2011, directed to study the feasibility of having the powerhouse near the Mangdechhu dam for additional power generation from the Mangdechhu project. Based on the techno-economic and socio-environmental assessment, the alternative project layout, with dam site D1 and powerhouse PH1 at Tangsibji, was found less feasible, compared to other alternatives. Therefore, in the Feasibility Study carried out in 2012, only 4 alternatives with the powerhouse located near the Mangdechhu dam were studied,

which recommended Alternative 3 as the best option, with the dam at Lorim (D2) and the powerhouse at Norbuodi (PH2); the Detailed Project Report (DPR) study was conducted in 2013 for this project alternative. The project envisages an installed capacity of 118 MW, producing an average annual energy of 491.52 GWh from the Nikachhu powerhouse and additional energy of 323.77 GWh from the Mangdechhu powerhouse.

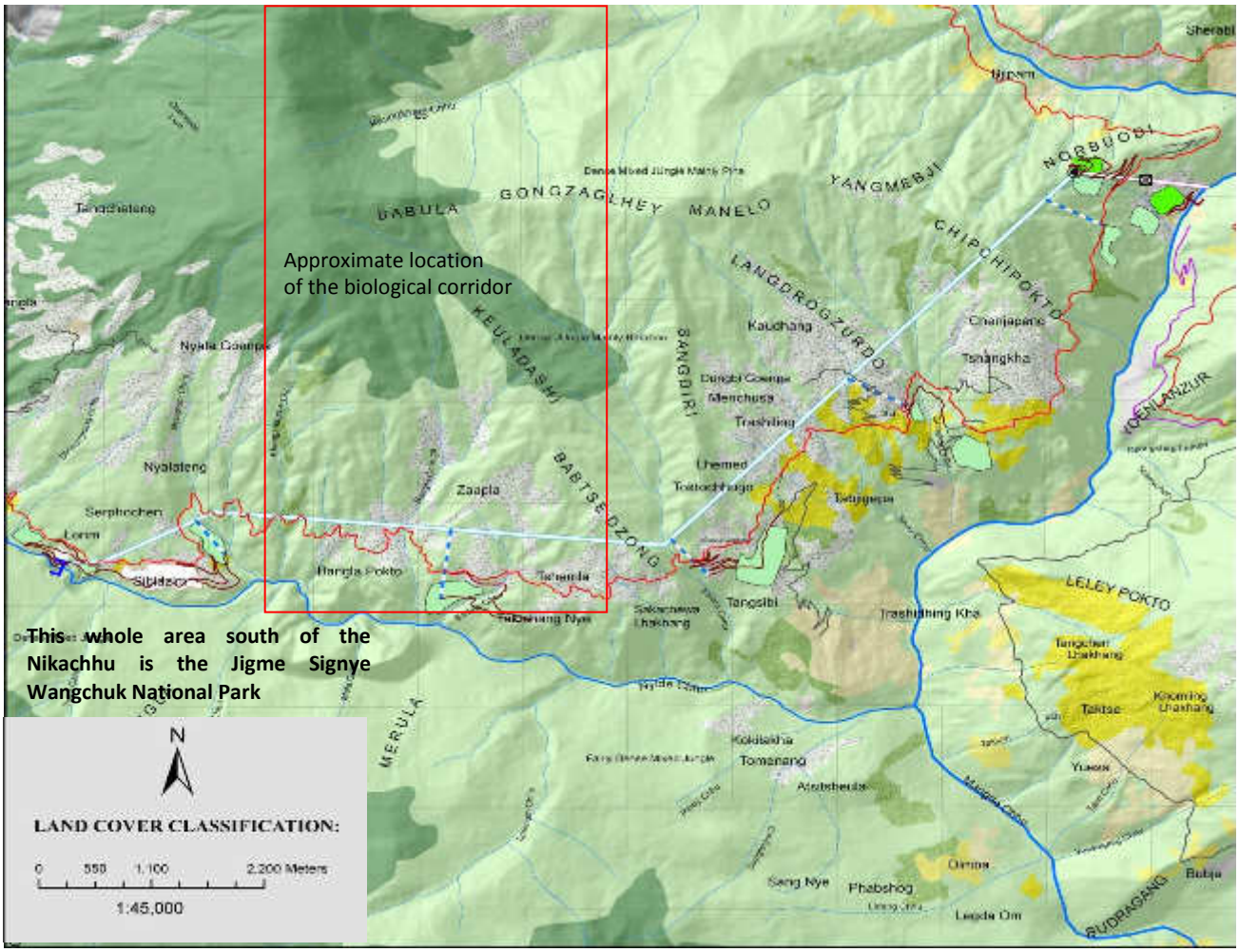
Project Description

The Nikachhu project is a run-of-river scheme. The Dam will be located approximately 6 km downstream of Chendebji Chorten (see Figure ES-1). The Nikachhu is a tributary of the Mangdechhu with its catchment north and south of the road (the National Highway) running from Pele La to Tangsibji. The topography in the area is characterized by steep slopes and deep gorges, almost all forested, with approximately one third of the catchment area lying above 4,000 m elevation. The river itself is quite inaccessible, and no communities are actually located along its reach to the Mangdechhu. The dam will be about 33 meters high above the river bed and will create an impoundment (small reservoir) of 12.28 acres (4.9 ha). The intake will connect to the Head Race Tunnel, which will run 12.14 km to the underground powerhouse cavern to be located at Norbuodi. A Tail Race Tunnel will take discharge water to the reservoir above the Mangdechhu dam. Nikachhu power will be evacuated through an 18.6 km transmission line running to Yurmo, where it will be integrated into the pothead yard of the Mangdechhu Hydropower Project. Based on a detailed land demarcation survey and socio-ecomonic assessment, the project will impact only about 3.57 acres (1.43 ha) of private land belonging to 11 households and a public institition. 0.6 acreof land wil be affected by transmission line tower footing. The rest will occur on Government land. After construction, the only visible components of the project will be the dam, the permanent staff colony, related access roads (road to the dam; road to the powerhouse and surge shaft; road to Adit #3, which will be used as the maintenance road for the HRT) and the transmission line. These permanent above-ground components will take up only 46.15 acres (18.5 ha) of land. Tunnelling will generate about 1,514,879.48 m^3 muck, which will either be recycled, or disposed at sites that will then be terraced and re-vegetated. Temporary land acquisition required for the project (the access roads, muck disposal sites, and Contractor facility establishment) will be only 207.54 acres (83 ha). Some of these facilities may remain available to the local community (for example, some access roads, and the terraced and re-vegetated muck disposal sites). All other construction related locations will be revegetated and allowed to revert to a natural state. Trees that are cut for the project will be compensated with tree planting in an area 2 times larger than the cleared project areas. A quarry will be developed to provide construction material for the project. During the peak construction period, there will be about 80 technical and non-technical project staff and about 67 staff during the O&M stage.

Regulatory Framework

Review of legal instruments relevant to the project was carried out. This includes the constitution of Bhutan, which mandates the state to maintain forest cover of 60% at all times. Bhutan 2020: A Vision for Peace, Prosperity and Happiness discusses milestones to achieve full hydropower generation by 2020. This policy document supports "sustainable and equitable economic development", which is the first of the four pillars of gross national happiness. The basis for the environmental clearance process for the project is the Environmental Assessment Act 2000, in which the National Environment Commission provides oversight of the clearance process. There are various relevant sections of the Acts and Regulations applicable to both the project construction and operation phases, which have been summarized to facilitate compliance of the project with all

Figure ES-1: Project Area and Project Components.



standards and procedures incorporated therein. These include: the Environmental Assessment (EA) Guideline for Hydropower 2004; EA Guideline for Transmission and Distribution 2004; EA Guideline for Highways and Roads 2004; Environmental Assessment Guidelines for Mines 2004; Environmental Discharge Standard 2010; and, Land Compensation Rates 2009.

Furthermore, in order to obtain an environmental clearance for the project, the EA Act 2000 mandates a requirement for a "No Objection Certificate (NOC)" from the affected agencies, communities, and individuals. For the Nikachhu project, a NOC is required from the following entities namely: Department of Forest and Park Services (Wildlife Conservation Division (WCD) for project areas falling within the boundary of a protected area and Forest Territorial office for the one falling in State Reserve Forest Land); Private Land Owners, as the project is envisaged to acquire private land; and, Department of Roads, as access takeoff points to the project areas are required to be taken from highways and feeder roads, Trongsa Dzongkhag Administration and Gewog Administration Office for project imolementation in their jurisdiction. Clearances from other stakeholders like Departmemt of Culture and Bhutan Power Corporation has also been sought.

Review was also carried out of Bhutan's obligations to the international environmental conventions. Of the twelve conventions that Bhutan is party to five are relevant to the project. They are: the UN Framework Convention on Climate Change; the UN Convention on Biological Diversity; the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); and, the Kyoto Protocol to the United Nations Framework Convention on Climate Change; and, the United Nations Convention to Combat Desertification (UNCCD). There are no elements of the project that contravene the direction and intentions of these conventions and the project will offset a significant amount of carbon dioxide emissions. The legal review also included the ADB Safeguard

Policy Statement (2009), which addresses the environment, involuntary resettlement, and indigenous peoples. This document (the ESIA) is responsive to all the requirements in the SPS.

Baseline Environmental and Socio-Economic Information

Baseline information for environmental and socio-economic features in the project area was collected during field surveys and local consultations, as well as from the primary and secondary scientific literature for Bhutan. Information was categorized as follows: physical environment; biological environment; and, socio-economic features. The baseline information is intended to help identify vulnerabilities in the zone of influence of the project (within several kilometers) so that the impact assessment is properly focused and informs the development of appropriate mitigation measures.

The project area is located in a steep topography with an average gradient of 45% and maximum gradients exceeding 98%. Gneiss and granite make up much of the geology of the project area. Only one landslide has been documented in the project area. The Nikachhu Project falls within a low seismic hazard zone. The land type is dominated by forest (87%), with natural pastures (8%), arable land (about 2%) and other uses making up the rest. Most of the forest is broadleaf and the project area falls within this forest type, which is considered degraded on the north side of the Nikachhu (where all project components will be located). The south side of the Nikachhu is taken up by Jigme Singye Wangchuck National Park. Air quality, noise levels, and water quality in the project area all reflect a pristine environment, with no evidence of contamination from human activities. The Nikachhu catchment area upstream of the proposed dam site is about 373 km^2. There are no glacier-fed lakes in the catchment. The average lean flow of the Nikachhu at the proposed dam site is 4.8 m^3/sec (recorded between December and March). There are 26 tributaries between the proposed dam site and the confluence of the Nikachhu and the Mangdechhu; 11 of these are perennial. These tributaries contribute on average 2.88 m^3/s flow in a year. The climate in the project area is typical for central Bhutan, with summer temperatures up to maximum of 29^{o}C and minimum winter temperatures as low as -10^{o}C. Most of the rain falls during the monsoon (June-September); river discharge rates reflect this seasonality, with peak discharge of about 43 m^3/s in July and August.

Floral taxonomic diversity was highest at the dam site with 41 species per 100 m^2 and lowest around Adit 4 (mid-way between the proposed dam site and the powerhouse site) with 12 species. The powerhouse area has the second highest floral diversity with 37 species. The large trees are dominated by *Quercus* species (oak); they are dominant throughout the project area. The area also supports orchids and climbers due to high moisture levels. No endemic or endangered floral species were recorded in the project area, nor reported by the park staff. Mammals observed in the area include Sambar Deer, Barking Deer, various squirrels, and Assamese macaque. Endemic and

protected mammals were not observed during the survey; however, park officials have reported the existence of the Golden Langur (endemic), Tiger, Common Leopard, Black Panther, Leopard Cat, Asiatic Golden Cat, Himalayan Black Bear, Red Panda, and the Himalayan Serow in the park area. These animals have access to wide swaths of natural forested habitat throughout the biological corridor and the National Park. The project area occurs at the southeastern tip of one of three large tiger habitats in Bhutan; therefore not in the main cluster of tiger sightings. No endemic or protected bird species were recorded in the project area, nor reported by local communities and park staff.

There were two aquatic surveys undertaken. Only one fish species (the brown trout, an introduced species) was found in the Nikachhu. Brown trout are found throughout Bhutan and do not migrate long distances. No other fish were observed in the river, possibly reflecting the presence of several large waterfalls between the proposed dam site and the confluence of the Nikachhu and the Mangdechhu, which prevent upstream movement by fish. The Nikachhu is clear, fast flowing, and turbulent, with a low temperature (a typical mountain river). Therefore, the river does not support an extensive macroinvertberate benthic community.

The local community was surveyed. Most of the local community is engaged in farming (66%), with only a small percentage in business or Government service. Almost the whole community has substantial houses, with steel roofs and stone walls; there is full access to electricity, schools, health care, drinking water, and sanitation facilities. In terms of education, 60% are uneducated; 22% have been to school, but very few have any higher degrees; 47% of the local community has no particular skills. There are no share croppers in the project area; most of the land that is owned is cultivated by the owners, although there is a significant amount that is fallow, due to a shortage of labor and wildlife incursions. Rice and maize are the main crops in the area. The main shocks suffered by the local community include crop failures and loss of livestock to predators. Within the project area, there are 11 shops, 2 resorts, and a hotel. In terms of poverty, 7 households in the survey area are below the poverty line of Nu. 1,097 per month however none of these households are affected by the project. All households that may be affected by the project are positive about the project (they do not anticipate negative environmental impacts), and will receive adequate compensation for project access to and use of their land.

Expected Impacts and Proposed Mitigation Measures

All project interactions with environmental and socio-economic features in the zone of influence of the project were examined, first of all by looking at the implications of each project activity on each environmental and socio-economic feature, and then by examining the accumulated impacts of all project activities on each feature in the zone of influence. The expected impacts and proposed mitigation measures are summarized below.

Slope/Sediment Stability: The main concern is with road cuts (for the access roads), and muck disposal. These operations will require slope stabilization prior to and during work; therefore, the risk of sediments going down slope, knocking down trees and entering watercourses can be managed. With the exception of the dam site, and Adits 1 and 2, most of these works will be at least 500 meters from any rivers. There are smaller risks from blasting, the quarry operation, and installation of the transmission tower foundations. All new sediment slopes will eventually re-vegetate. This can be accelerated by planting appropriate steep slope vegetation as soon as possible after the slope has been created, and terracing as much as possible.

Climate: The project will not impact climate *per se.* Future climate variation may have an impact on annual rainfall amounts and seasonal patterns, which may affect the project power production modeling (modeling indicates a slight increase in rainfall and therefore river discharge over the next 50 years).

Air Quality: All air quality impacts will be localized and transient during pre-construction and construction. These can all be mitigated with exhaust and dust controls. Local communities will not be immediately adjacent to work sites. Workers can wear masks to reduce health impacts of dust. Air quality over time could improve, if there is less burning of fuelwood and hydrocarbons for heat and cooking (replaced by electricity).

Noise Levels: Noise increases will also be localized and transient during pre-construction and construction. Noise increases can be managed with exhaust controls and workers wearing ear protection. Local communities will not be immediately adjacent to work sites.

Hydrology: The main impact, of course, is a reduction in downstream river discharge, as a result of the diversion dam. A minimum environmental flow of at least 10% of average lean season flow, increasing to more than 15% between the dam and the confluence with the Mangdechhu (from perennial and seasonal tributaries), will compensate. The “knock-on” effects of reduced downstream discharge include reduced river width below the dam, altered aquatic habitat, and less volume of habitat for brown trout. A dam burst would create a sudden change in downstream hydrology (flash flood, with rapid dissipation downstream). However, dam burst is a very low probability event given the size of reservoir.

Groundwater: Linkages between the project and groundwater are difficult to predict, but are expected to be minimal, and no communities are reliant on wells. A fuel spill could possibly contaminate groundwater, and blasting could create a localized shift in aquifer characteristics that might affect percolation and recharge, as well as springs. Reduced discharge in the downstream of the Nikachhu could reduce aquifer recharge, which may be occurring as a normal linkage between

the river and the aquifer. Given the relatively high rainfall amounts in this area, and the many tributaries coming from heavily forested watersheds, any groundwater effects would likely not be measurable.

Surface Water Quality: Transient reductions in surface water quality, caused by pre-construction and construction activities (most likely sediment intrusions into the river), should be of little concern, as they will very quickly be flushed downstream during most months (April-November). Turbidity plumes created in the lean season will take longer to flush out. Work site management, and sediment controls in particular, will reduce most risks of this nature. Bunded fuel storage, sewage treatment on-site, and proper management of worker camps should minimize the risk of contamination of surface water by organic and hazardous materials. Operation of the dam will create a flooded area, which, while constantly circulating and exchanging (due to inflow to the headrace), could lead to some risk of reduced water quality. Upper watershed management will be encouraged, although this area will remain heavily forested, in any case, so sediment inputs to the reservoir should be minimal. Occasional sediment purging from the desilting chambers could cause some turbidity plumes downstream, but this will likely be done during the high discharge monsoon season, when the river is already carrying a higher sediment load, and discharge volumes are quite high, which will accelerate flushing. Reduced discharges in the lean season (with minimum environmental flow) could create a higher risk of reduced water quality in downstream areas.

Biodiversity: Land acquisition and related clearing (mostly in degraded forest areas, for the dam and powerhouse components, and the transmission line) will reduce available habitat (vegetation) and may therefore reduce available area for wildlife. However, none of these project sites are critical or unique in terms of biodiversity (as the large adjacent area, especially the National Park, which will remain undisturbed, provides the same of better habitat conditions) , and no vulnerable or endangered species are likely to be affected. Given the extremely small percentage of the habitat/biodiversity complex that exists in the Trongsa area and in adjacent areas that may be taken over by the project (perhaps only 1% within the roaming range of large mammals), no net loss of species, or incremental pressure on specific species, is likely to occur. It is therefore expected that no significant irreversible change in local biodiversity will occur as a result of the project.

Protected Areas/ Biological Corridors: The dam site construction activity and the flooded area above the diversion dam will impinge on the buffer zone of the Jigme Signye Wangchuck National Park, but in an inaccessible, steep slope area that does not support extensive forest cover or wildlife access. This area of impingement represents <0.0014% of the total area of the Park (0.024 km^2 of 1,723 km^2 of total park area which is negligible). The “pond” above the diversion dam can be made a Park interpretation feature (or limited recreation area; fish stock area), which is potentially

positive. Construction activity at Adit 2 in the Biological Corridor will be temporary (over about 1.5 - 2 years), and represents only 12-15% of the width of the eastern corridor (there are three connecting JSWNP), or about 0.0047% of the width of these three corridors. The eastern corridor is already crossed completely by the National Highway. Temporary project activity in the eastern corridor is therefore not expected to disrupt wildlife movements, most of which occur at night, when construction activity will be minimized. The transmission line alignment does not pass through any significant wildlife habitat (much of it is barren or common broadleaf forest); there are no particular concerns for wildlife disturbance during the temporary construction activity for the towers and hauling the cable.

Vegetative Cover/ Diversity: All land clearing will occur on the north side of the Nikachhu, where forests have been degrading over the last 30-40 years (it is not protected *per se*), with intrusions for pasture and dryland cultivation, as well as wood extraction. No unique habitats or protected/ vulnerable species will be cleared, as the cleared area is a very small percentage of similar vegetation and habitat all along the National Highway in this area. While some cleared areas will remain permanently converted to project sites, they will be enhanced with plantings, and all temporarily cleared areas will be allowed to revert to natural vegetative cover, or will be planted with specific species.

Forest Resources: As noted above, no vulnerable or protected tree species will be cut. All trees that will be cut will be compensated for, by replanting appropriate species at in an area that is 2x the area that will be cleared for the project. Much of the cut wood can be used for fuel.

Wildlife (Terrestrial, Avian): No specific unique wildlife habitats will be affected by the project, and the project will not create any large barriers to wildlife and bird movements. Any disruption of wildlife behaviour will be temporary (just during pre-construction and construction), and animals (including birds) will be able to move around or over construction sites. Wildlife are at risk from poaching (construction workers), but this potential activity will be disseminated as an illegal activity and monitored.

Aquatic Habitats: Aquatic habitat is at risk from sediment and hazardous material inputs, if work site management and mitigation measures are not properly designed and implemented. The most pervasive risk is sediments entering the watercourses. Fortunately, the creeks, tributaries, and the Nikachhu are currently fast-flowing (in most months), and any sediment inputs will likely flush out quite quickly (in most months, except during the lean season). Any intrusion or contamination of aquatic habitat during the pre-construction and construction phases would be transient. Formation of the reservoir above the diversion dam will be a positive feature (diversity of aquatic habitats),

whereas reduction in discharge below the diversion dam (minimum environmental flow) will reduce the volume of river habitat, but not necessarily the quality of that habitat. Volume will be made up over the distance between the dam and the confluence with the Mangdechhu by seasonal and perennial tributaries. During project operation, there will be occasional turbidity pulses in the Nikachhu, due to cleaning of the desilting chambers, but this will occur during the monsoon, when river discharge is high and suspended sediment levels are at their annual peak, in any case. A dam burst would cause a rapid scouring effect in the downstream of the Nikachhu, which would create a significant alteration of existing aquatic habitat; this would require several years for recovery.

Fish Stocks/ Migration: During pre-construction and construction, fish (specifically brown trout) will continue to have access to the Nikachhu, with unrestricted movements (going through the diversion tunnel). They may be at risk from poaching and from sediment and hazardous material spills into the river. During project operation, fish will continue to be able to make movements downstream (they will be screened from the headrace intake, going through the spillway). They will not be able to move upstream past the diversion dam, but, in any case, brown trout do not make long migrations in the Nikachhu, due to the series of waterfalls between the dam site and the confluence with the Mangdechhu. The reservoir above the diversion dam will provide a positive opportunity for fish stocking.

Use of Farm Land: Temporary and permanent land acquisition for the project will result in loss of access to farm land (mostly in the eastern section of the project area and along parts of the transmission line alignment); this will be compensated. After construction and after installation of the transmission line, most areas will be accessible again for pasture and/or dryland cultivation.

Aesthetics: The main negative impact on visual aesthetics in the project area will occur during construction, as a result of clearing, site work, and heavy equipment and vehicles on the road. This will obviously stop when the project construction is finished. Persistent negative visual impacts will be minimal, as the temporary project sites will revert to vegetative cover, and permanent sites will be planted with suitable vegetation. The dam and other infrastructure, as well as the reduced size of the Nikachhu downstream (all negative for visual aesthetics) will fortunately not be very visible from the highway or inhabited areas. The reservoir above the diversion dam will be a positive visual feature, and will have some potential for Park interpretation and recreation, depending on how the Park allows public access to this area.

Business/ Employment: The project will create opportunities for employment and supplier business, for the duration of the project construction. However, their sustainability (jobs and businesses) will be at risk when the project construction is complete. This risk needs to be disseminated and

understood by the local community, as future infrastructure development in the area, and related opportunities, remain unclear.

Services: Improvement of parts of the National Highway, and creation of access roads near local communities, will facilitate local transportation. The project will also increase access to electricity.

Social/ Cultural Stability: There is some risk of social and cultural instability, as up to 2,000 workers will be involved with the project, and many of these will be coming from outside the region (possibly India). While Bhutan is increasingly familiar and comfortable with worker influxes, the risk still remains that local communities may not easily accommodate their presence in the area, especially if they engage in illegal activities. However, the area is already familiar with and has adjusted to this situation with the Mangdechhu hydropower project over the last 3 years.

Health/ Safety: The main health and safety risks are associated with construction activities, and the risks are faced by workers; they will be briefed on risks and issued with PPE (personal protection equipment). Local communities may also face some risk in using the National Highway and local access roads, when construction equipment (heavy equipment and vehicles) are operating on the roads. Access to the reservoir may be a public safety concern; secure fencing is proposed. The option for public access to some part of the reservoir and provision of National Park interpretation needs careful study. A dam burst could present a risk to public safety, but it is expected that no communities will be within the flash flood zone, in the event of a dam burst. A warning system will, nevertheless, be installed and disseminated, in case people are on or near the downstream section of the Nikachhu at the time of pending dam failure.

The Environmental Management Plan (Part 2) incorporates all the mitigation measures proposed above, and accommodates monitoring to ensure their performance. The EMP costs represent about 1.19% of the total project cost.

Conclusions

The impact assessment process has indicated that there are no significant negative environmental and socio-economic impacts associated with the proposed Nikachhu project that cannot be mitigated to negligible or acceptable levels. All significant issues were screened out during the consideration of alternative locations. Furthermore, the relatively small scale of the project footprint in an immediate project area of about 253 acres (101 ha) in an area that has an expanse of similar habitat in all directions, and which does not support unique or critically vulnerable flora and fauna, is the main factor in keeping environmental and socio-economic impacts at an acceptable and manageable level. Experience with similar projects in Bhutan indicates that the temporary negative consequences of construction work can be managed with “best practice” measures to minimize

sediment mobilization, reduce noise and air quality issues, and contain waste, so that there is no degradation of terrestrial and aquatic habitats. Trees that have to be cut will be replaced in a larger re-vegetated area, and land that is required for the project will be compensated. Impingement on the buffer area of the National Park will have no ecological significance (as it is a very steep slope inaccessible to most wildlife), wildlife in the area will still have access to wide swaths of natural habitat for refuge and movement, the very limited fish population in the river will still exist above and below the diversion dam (no fish migration is evident in the Nikachhu, due to waterfalls), and minimum environmental flow (10% of average lean season flow at the dam, and increasing continuously downstream) will maintain an adequate aquatic habitat in the downstream section.

There is full local community acceptance of the project (very few families are directly impacted by the project, and no relocation is required). The project will help bring significant power service reliability to Bhutan and local and national economic benefits, as well as significant greenhouse gas emission reductions.

All required mitigation measures and respective monitoring of their performance are documented in Part 2 (Environmental Management Plan); this EMP will become the *modus operandi* for the project, ensuring that predicted impacts are well-managed, and that accountability for mitigation performance is in place.

Given the observations and conclusions from the impact assessment process documented above, the project appears to be acceptable for implementation, as designed, according to Royal Government of Bhutan and ADB standards.

1 INTRODUCTION

1.1 Background

Druk Green Power Corporation Limited (DGPCL) was formed on January 1, 2008, with the amalgamation of the hydropower corporations in Bhutan. DGPCL is mandated to look after the existing power generating facilities and to accelerate hydropower development in the country. The Corporation currently operates five power plants with an installed capacity of 1,480 MW, and will be taking over other power plants for operation and maintenance as and when new power plants are commissioned. The Corporation will also be taking up new hydropower projects on its own or under joint ventures. Tangsibji Hydro Energy Ltd (THyE), a 100% DGPCL owned subsidiary company incorporated on April 25, 2014 shall be implementing the project.

As per the updated Power System Master Plan (PSMP) of Bhutan (2004), the installed capacity of the Nikachhu Hydropower Project (NHPP) was envisaged as 208 MW. DGPC conducted a Pre-Feasibility Study (PFS) that was concluded on 31 December 2011. The PFS investigated six project alternatives, considering geological stability, environmental and social concerns, and economics. Among the six alternatives, Option #3, which locates the dam at Lorim and the power house at Norbuodi (near Trongsa), was recommended as the best option (see Figure 1-1). With this option, tailrace water will be discharged into the reservoir above the Mangdechhu Dam in order to optimize power generation in the lean season. This combined scheme was approved by the DGPCL Board in its 30th Meeting.

Bhutan Consultants & Research (BHUCORE) was awarded the contract to conduct the Environmental and Social Impact Assessment (ESIA) of the Nikachhu project on June 1, 2012. Three deliverables make up the requirements for BHUCORE, including: 1) the Environmental and Social Impact Assessment Report; 2) the Environmental Management Plan (EMP); and, 3) the Resettlement Plan (RP). As noted in the ESIA preamble, revisions to the ESIA report (this version) have been made by PWC India consultants.

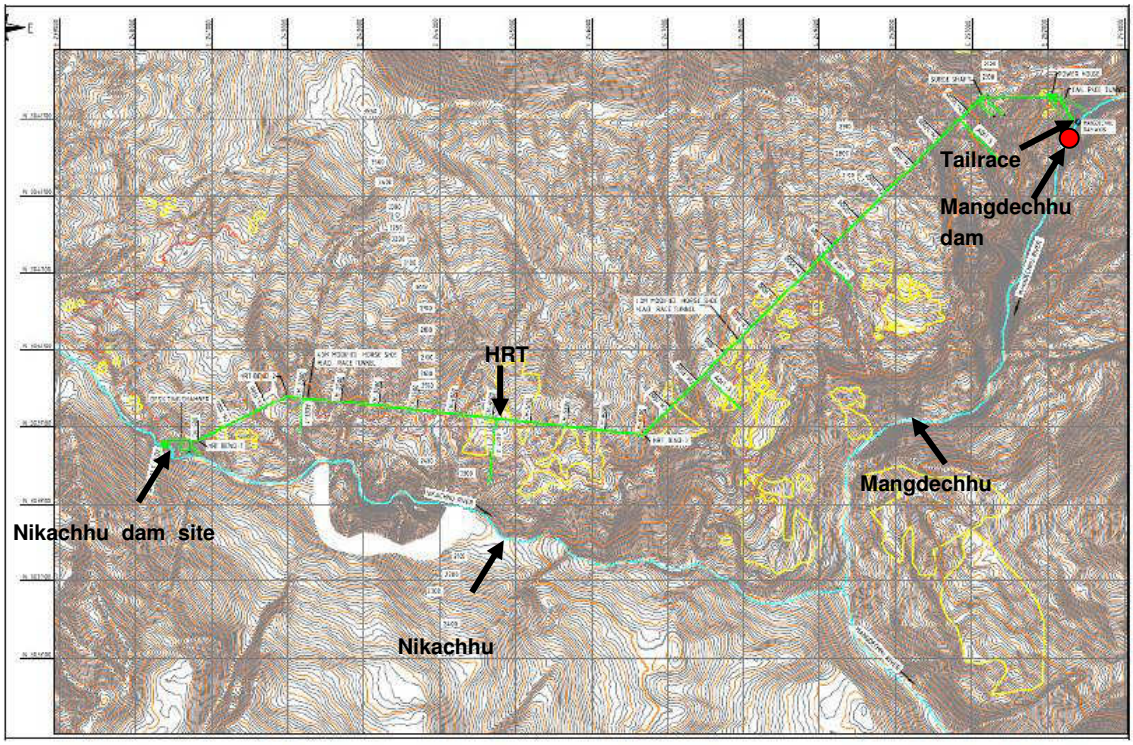


Figure 1-1: Nikachhu Project locations.

1.1.1 Applicant Details

As per the environmental guidelines of Bhutan, it is required that the applicant provide accurate contact details. These are noted below:

1. Name of Project: Nikachhu Hydropower Project (NHPP)
2. Applicant Name: Dasho Chhewang Rinzin
3. Mailing address: Projects Department, Druk Green Power Corporation Ltd, Thimphu Bhutan Tel.: +975 2 339871/339873; Fax: +975 2 323853; www.drukgreen.bt
4. Name of environmental focal person (EFP): Pratigya Pradhan (Ms.), email: manager.projects@drukgreen.com or pratigyap@hotmail.com
5. Designation of EFP: Manager (Civil)
6. Qualification of EFP: Master of Science
7. Telephone # of EFP: +975 1787 6198
8. Contact details of Environmental Consultant: Karma Jimba, Tel: +975 7710 6111, Bhutan Consultants & Research (BHUCORE), Thimphu, Bhutan, Post Box: 955, email; karma_jimba@hotmail.com

9. Contact details for 2013 revisions to ESIA: Suvendu Bose, Senior Manager, PricewaterhouseCoopers Pvt. Ltd., Plot No. 56&57, Block DN, Sector-V, Salt Lake, Kolkata 700 091, Tel: +91 (33) 23579101; email suvendu.bose@in.pwc.com

1.2 Objectives

The main objective of this ESIA is to anticipate and effectively address all identified environmental and social concerns associated with the NHPP, in line with the Kingdom of Bhutan's laws and policies, as well as with Safeguard Policies of the Asian Development Bank (ADB). The ESIA should enable DGPCL to seek the remaining environmental clearances from the National Environment Commission Secretariat (NECS), the country's environmental authority, and to expedite the financing process with ADB. All residual environmental and social issues are expected to be addressed in the Environmental Management Plan (EMP) and the Resettlement Plan (Partss 2 and 3, respectively), as well as in the related consultation and information dissemination processes. Currently, all the statutory clearances including Environemnt Clearance required for the project has been accorded.

1.3 Scope of Work

The scope of work for the ESIA includes a detailed environmental and social assessment of all NHPP components, including the dam, head race tunnel, ADITS (access tunnels), access roads, surge and pressure shafts, tailrace tunnel, power house, temporary and permanent camps, muck disposal sites, quarry sites, and construction camps, during the pre-construction, construction, and operation phases. The assessment covers areas upstream and downstream from the dam (basically the whole catchment area of the Nikachhu). The specific details that are addressed in the ESIA include:

a. The baseline data related to the project physical environment, air quality, noise levels, water, hydrology, climate, geology, biological environment, land use, the socio-economic aspects, and the historical context and cultural environment;
b. Review of relevant policies, laws, rules and directives;
c. Impact identification, assessment and quantification (for the pre-construction, construction, and operation phases);
d. Formulation of mitigation measures (for all phases);
e. Articulation of these in the EMP;
f. Formulation of the Resettlement Plan (RP); and,
g. Presentation of the findings of all steps noted above.

Consultations with government agencies (Wildlife Conservation Division, Department of Forests and Park Services, and Jigme Signye Wangchuck National Park staff, and the latter providing input

to the EMP) and affected people, local community members, and women's groups (in both Thimphu and the Trongsa area) were an important part of the impact assessment process. All consultations over the period 2012-2014, including attendees and main observations, have been recorded in separate appendices (I, II, and III). There have been more than two environmental issue consultations, and the results of the draft ESIA were presented again to local communities at the end of 2013. Local language summaries were also provided. Furthermore, the National Environment Commission has surveyed the project site, and undertaken their own consultations, which have informed this revised version of the ESIA. Environmental NGOs were also consulted, including the Bhutan Royal Society for the Protection of Nature and the WorldWide Fund for Nature (WWF provided their tiger data).

1.4 Report Presentation

The three required outputs under the Terms of Reference (ToRs) for this exercise include the ESIA, EMP and RP (Parts 1, 2, and 3). The ESIA (Part 1) is presented in six chapters as follows:

- Chapter 1 provides the introduction, with a background on the project, environmental clearance applicant details, and the scope of work.
- Chapter 2 provides a technical description of the project. The pre-feasibility study considered six alternatives for the NHPP and among those, alternative #3 was selected as the best option from technical, environmental, social, and economic perspectives. The project technical description is therefore focused on alternative #3.
- Chapter 3 presents the six alternatives that the DGPCL considered during the feasibility analysis (as noted above), in order to arrive at the best option (alternative #3). It also presents the two scenarios: "Having a Project" versus "Not having a Project" (maintaining the *status quo,* in the latter case).
- Chapter 4 presents an extensive review of Bhutan's laws and policies relevant to the NHPP. It also contains a review of international environmental obligations that Bhutan must comply with, and the ABD safeguards policies for hydropower projects, that this ESIA is responding to.
- Chapter 5 includes details on the baseline data for environmental conditions in the project area (current features and conditions, pre-project), including the methodology used to obtain the baseline data. These are supported with the additional details in the Annexes and Appendices.
- Chapter 6 identifies the potential environmental and social impacts, as well as the concepts for mitigation measures, which are then elaborated in the EMP (Part 2).

A Grievance Redress Mechanism (GRM) has been defined as part of the social impact assessment and Resettlement Plan (RP) process. The current version of the GRM has now been included in

the EMP (as it is mainly a management process), as well as in the RP, since the ESIA/EMP and the RP may go on separate tracks for approvals from the Royal Government of Bhutan and ADB.

1.5 Consultants

This ESIA has been carried out through a combination of local and foreign expertise under the management of Bhutan Consultants & Research (BHUCORE). Figure 1-2 shows the organization of the consultants and their responsibilities. BHUCORE also liaised with the environmental and social consultants of PricewaterhouseCoopers (PWC) India, who were assigned to provide oversight for the ESIA under the Technical Assistance (TA) of ADB to DGPCL. Other PWC consultants were then responsible for the revisions and editing undertaken in 2013.[1]

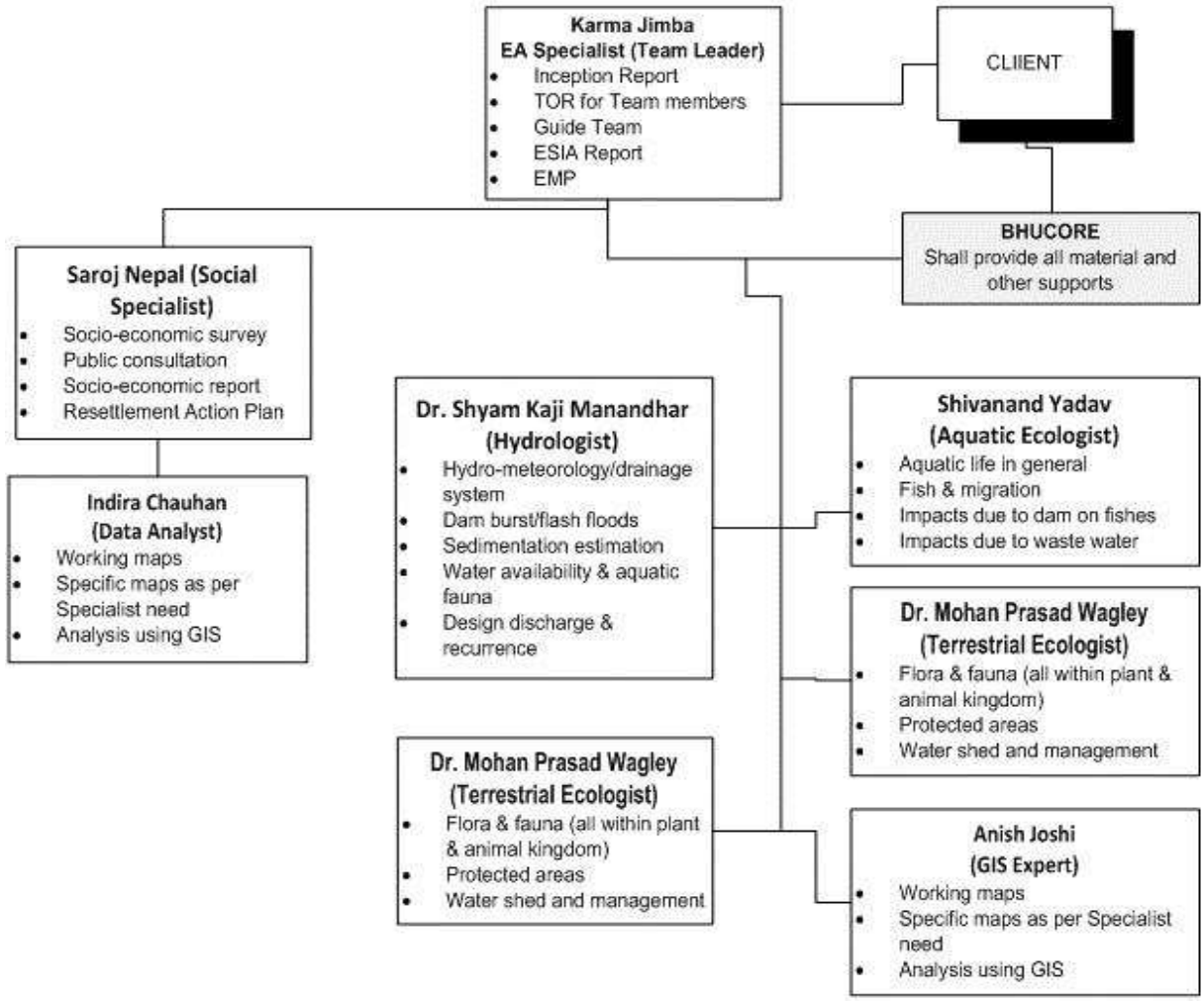


Figure 1-2: Consultant Organization for the Nikachhu ESIA (original draft).

[1] The Bhucore aquatic ecologist, Shivanand Yadav (from Nepal), has an MSc in Aquaculture (1993-1995) and MSC Zoology training in inland fisheries and aquaculture; the Bhucore terrestrial ecologist, Dr. Mohan Prasad Wagley (from Nepal), has an MSc in Range Management and Ecology (1980-1982) and a PhD in Watershed Management (1997-2000). The PWC ecologist, Deki Yonten, has an MSc (Yale) in Forestry and worked for twelve years in Department of Forests (Wildlife Conservation Division); the fish specialist, Dr. D.B. Gurung, Dean, Academic Affairs, College of Natural Resources, Lobesa, has more than 20 years experience in natural resources.

2 PROJECT DESCRIPTION

2.1 Introduction

DGPCL is taking a lead role in accelerating hydropower development in the Kingdom. Towards fulfilling this mission and amongst several activities undertaken by the Corporation, NHPP is one of the first Hydropower Projects that is being managed right from the prefeasibility stage.

As per the updated Power System Master Plan (PSMP) of Bhutan (2004), with the original concept for Nikachhu, the installed capacity of the Project was envisaged as 208 MW. The dam site was proposed at a location named "D1" with a river bed elevation at 2,240 masl. The height of the concrete dam was proposed to be 23 m above the river bed level.

The Department of Energy (DoE), Royal Government of Bhutan (RGoB) allocated the Pre-Feasibility Study (PFS) of the Project to DGPCL in 2009. The PFS report was submitted to DoE in November 2010. In the PFS report, Dam Site (D1) and the Power House (PH1) location were at the same locations as proposed in the PSMP; however, the proposed installed capacity was a little higher at 210 MW. In June 2011, the geotechnical studies at the feasibility level were completed. In the Pre-Feasibility Study (PFS), two alternatives were studied, considering the dam site at D1, located about 7.5 km downstream of Chendebji Chorten, and the powerhouse at Tangsibji. The Alternative 1 was aligned along the left bank of the Nikachhu and Alternative 2 was on the right bank. Considering the techno-economic and socio-environmental assessment, the project Alternative 1 along the left bank of the Nikachhu was found to be more feasible with an installed capacity of 210 MW. The ESIA studies for this alternative were prepared and submitted to NEC (vide letter no. DGPC/PD/Nikachhu/2011/1316 on 22nd April, 2011) for review and approval. Further, 6 alternatives with different configurations of the dam and powerhouse sites were studied as part of the PFS update, considering techno-economic feasibility and socio-environmental aspects. Subsequently, the Druk Green's Board, in its 30th Meeting held in October 2011, directed to study the feasibility of having the powerhouse near the Mangdechhu dam for additional power generation from the Mangdechhu project. Based on the techno-economic and socio-environmental assessment, the alternative project layout, with dam site D1 and powerhouse PH1 at Tangsibji, was found less feasible, compared to other alternatives. Therefore, in the Feasibility Study carried out in 2012, only 4 alternatives with the powerhouse located near the Mangdechhu dam were studied, which recommended Alternative 3 as the best option, with the dam at Lorim (D2) and the powerhouse at Norbuodi (PH2); the Detailed Project Report (DPR) study was conducted in 2013 for this project alternative (see below, and Section 3 for more details on the various alternative sites).

The geological and geotechnical study showed that PH1 lies in fair rock conditions, but with high permeability, consisting almost entirely of garnetiferous micaceous schist and mica schist, with intrusions of quartz and dykes. From the geotechnical studies, it was concluded that the location of PH1 might have been feasible. However, the cost of construction was expected to escalate, due to the fact of high permeability at PH1. Keeping in view the requirements for suitable geological conditions, and knowing the problems encountered at the Dagachhu Hydropower Project (which has led to time and cost overruns), alternative locations for the power house (PH2 and PH3) were identified. The idea was to locate the power house area in more competent geology, and also to enable the tail water to be released into the reservoir of the 720 MW Mangdechhu Hydroelectric Project and increase electricity generation there. Site PH2 was selected (see discussion below).

Based on the merits of combining the NHPP with the Mangdechhu Hydroelectric Project, Druk Green's Board, in its 30th Meeting, approved the study of the combined scheme, which ultimately led to the selection of Alternative 3, which includes D2 for the dam, and PH2 for the power house.

2.2 Location, Topography, Layout, and Accessibility

The proposed dam is located on the Nikachhu approximately 3.5 km downstream of Chendebji Chorten. Nikachhu is a tributary of the Mangdechhu, with the catchment north and south of the road running from Pele La to Tangsibji. The topography in the area is characterized by steep slopes and deep gorges, with approximately one third of the catchment area lying above 4,000 m elevation. The project area is found on topographic map Wangdue/Trongsa (sheet no. 78I/7, in a scale of 1:50,000, published by the Department of Survey and Land Records). Figure 2-1 shows the location of the project within Bhutan. The road distance from the capital city, Thimphu, to the project site is 162 km. The main East-West highway then runs along the Nikachhu from Chendebji Chorten past the intake and on to Tangsibji viewpoint, from where one can overlook the Nikachhu and Mangdechhu confluence (to the southeast). The distance between the intake and the viewpoint is 12 km along the highway. There is walking access (down a steep slope) to the dam site from the national highway, which is very close to the Nikachhu at that point. The end of the headrace tunnel and surge shaft area is directly accessible by a road off the national highway further to the east. All other construction access points will require new access roads off the national highway.

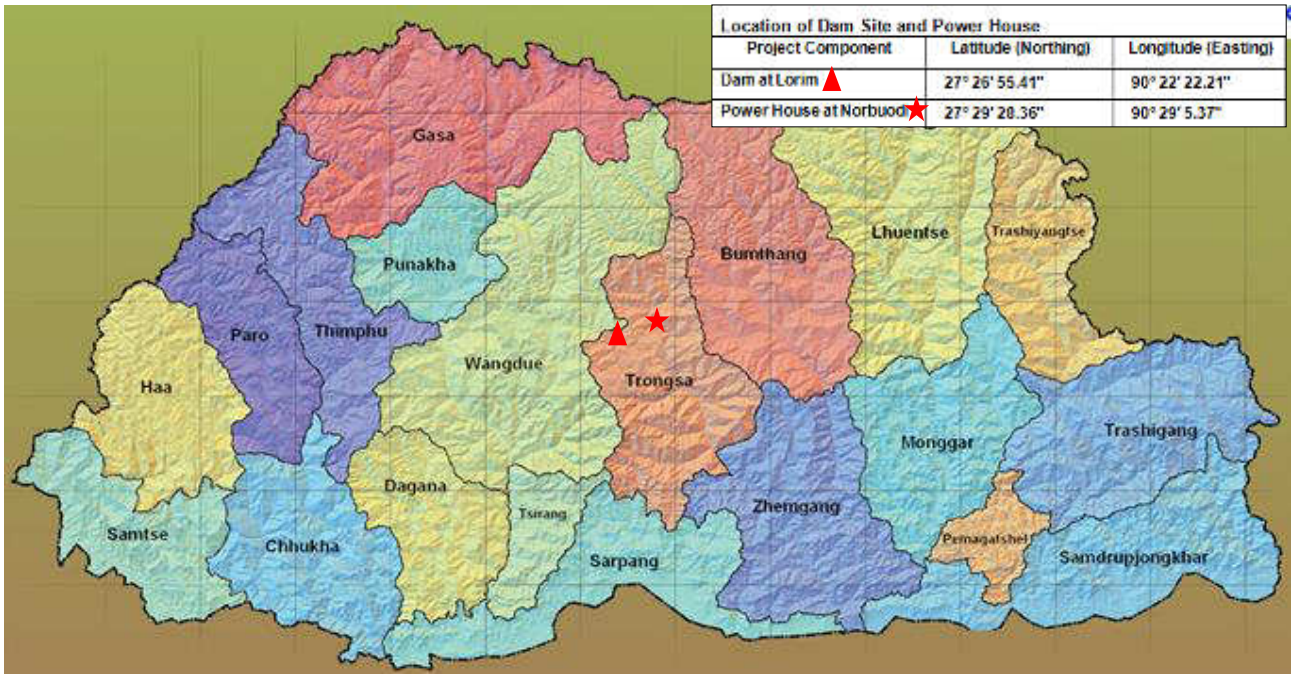


Figure 2-1: Location of Nikachhu Hydropower Project.

2.3 Design, Size, and Capacity

The salient technical features of the NHPP for the earlier scheme (Alternative 1) and the final DPR scheme (Alternative 3) are noted in Table 2-1 and Table 2-2 respectively:

Table 2-1: Salient features of the earlier scheme (Alternative 1).

Feature	Unit	Technical Details
Power Potential		
Design discharge	m^3/s	29.01
Net head	m	820
Installed capacity	MW	210
Design Energy (90% dependable flow)	GWh	843.61
Secondary Energy	GWh	122.52
Additional energy from Mangdechhu Power House	GWh	0
Total Energy	**GWh**	**843.61**
PLF (90% dependable year)	%	46
Hydrology		
Catchment Area	km^2	380
Design Flood	m^3/s	433
Average Annual Flow	MCM	580.6
Minimum Annual Flow	MCM	167.14
Dam		
Type		Concrete Gravity Dam
Dam top level	masl	2,290
River bed elevation	masl	2,240
Dam height above deepest foundation level	m	57
Crest length	m	170
De-silting Chamber		
Number of De-silting Chambers	No.	2
Width	m	7
Total Height of Chambers	m	8.5
Length of the Horizontal portion of De-	m	200

Feature	Unit	Technical Details
Silting Chambers		
	Head Race Tunnel	
Shape		Modified Horseshoe
Length	m	7500
Recommended dia. of tunnel	m	4.5
Design discharge	m^3/s	29.01
	Surge Shaft	
Type		Restricted Orifice
Number	No.	1
Diameter	m	9
Height	m	52
Pressure Shaft		
Number of Pressure Shafts/Unit Penstocks	No. (upto bifurcation)	1
Type		Steel lined
Diameter	m	2.5
Rated discharge	m^3/s	29.01
Length	m	850
Power House Complex		
Type		Underground
Powerhouse Cavern Dimensions	(LxWxH)	93x18x40
Size of Transformer Cavern	(LxWxH)	75x14x20
Number of units	No.	2
Capacity of each unit	MW	105
Type of Turbine		Vertical Pelton
Maximum Gross Head	m	861
Net Head	m	820
Tailrace Tunnel		
Shape		Modified Horseshoe
Length	m	1700
Size (diameter)	m	4.7

The information provided in the above table is based on the PFS level and is not detailed enough to compare directly to the DPR Scheme.

Table 2-2: Salient features of the final DPR scheme (Alternative 3).

Feature	Unit	Technical Details
Power Potential		
Design discharge	m^3/s	25.45
Rated head	m	516.4
Installed capacity	MW	118
Design Energy (90% dependable flow)	GWh	491.52
Secondary Energy	GWh	49.21
Additional energy from Mangdechhu Power House	GWh	323.77
Total Energy (Mangdechhu combined)	**GWh**	**815.29**
PLF (90% dependable year)	%	47.55
Hydrology		
Catchment Area	km^2	373
Design Flood	m^3/s	2,400
Minimum environmental flow	**m^3/s**	**0.554**
Average Annual Flow	MCM	515
Maximum Annual Flow	MCM	626
Minimum Annual Flow	MCM	451
Average 10-daily discharge	m^3/s	16.24
Maximum 10-daily discharge	m^3/s	79.21
Minimum 10-daily discharge	m^3/s	3.75
Reservoir		
Full Reservoir Level (FRL)	masl	2,292
MDDL	masl	2,283.8
Gross Storage	MCM	0.537
Live Storage	MCM	0.307
Dead Storage	MCM	0.230
Length of Reservoir	m	810

Feature	Unit	Technical Details
Reservoir Area	km^2	0.046
Dam		
Type		Concrete Gravity Dam
Dam top level	masl	2,295
River bed elevation	masl	2,262
Dam height from river bed	m	33
Crest length	m	90.25
Intake		
Top of Intake Structure	m	2,295
Invert Level of the Intake	m	2,275
De-silting Chamber		
Number of De-silting Chambers	No.	2
Width	m	7.5
Height of Dome	m	3.75
Vertical Height	m	4.5
Height of Hoppers	m	2.70
Total Height of Chambers	m	10.95
Length of the horizontal portion of De-Silting Chambers	m	175
Head Race Tunnel		
Shape		Modified Horse Shoe
Length	m	12,144
Diameter of tunnel	m	4.00
Design discharge	m^3/s	25.45
Velocity	m/s	1.96
Surge Shaft		
Type		Restricted Orifice Type
Number	No.	1
Diameter	m	10.5
Orifice area	m^2	2.01
Height (from orifice slab to operating	m	57.2

Feature	Unit	Technical Details
platform of gate)		
Top elevation	masl	2,319.7
Pressure Shaft		
Number of Pressure Shafts/Unit Penstocks	No. (upto bifurcation)	1
Type		Underground
Diameter	m	3
Rated discharge	m^3/s	25.45
Velocity	m/s	3.60
Length	m	932
Main Access Tunnel		
Diameter	m	7
Length	m	553
Power House Complex		
Type		Underground
Powerhouse Cavern Dimensions	(LxWxH)	66.675 mx 19m x 41m
Size of Transformer Cavern	(LxWxH)	61 m x 14 m x 27.1 m
Number of units	No.	2
Capacity of each unit	MW	59
Type of Turbine		Vertical Pelton
Speed of rotation	rpm	375
Generator Voltage	kV	11
Transformer and GIS		6+1 spare, 25 MVA, 1ph, 11/132kV
Maximum Gross Head	m	536.25
Rated Head	m	516.4
Tailrace Tunnel		
Shape		D-Shaped
Length	m	443
Size (diameter)	m	4

2.4 Project Components

The main components, defined for the best option with the dam at Lorim and the powerhouse at Norbuodi, are listed below:

1. concrete gravity dam;
2. coffer dam and diversion tunnel;
3. intake and de-silting chamber;
4. head race tunnel (HRT),
5. surge shaft;
6. pressure shaft;
7. powerhouse complex;
8. tail race tunnel;
9. main access tunnel and adits;
10. access roads; and,
11. power transmission line.

Ultimately, only the dam and small reservoir, intake and de-silting chamber, the end of the tailrace, permanent access roads, and transmission line will be visible above-ground. Details of each component are provided in the following sections, with a focus on technical features that have significance for the environmental and social impact assessment.

2.4.1 Concrete Gravity Dam and Reservoir

Table 2-1 shows the technical specifications of the dam and reservoir. The river bed level at the dam site is at an elevation of 2,262 masl. The dam height is expected to be 33 m above the river bed level. Based on the geological assessment at the site, the over burden thickness is approximately 1 – 3 m. The dam foundation will be about 5 m below the river bed level, for a total dam height of about 38 m (see Figure 2-2 for an example of a typical diversion dam). The dam will be located in a very steep gorge, with an almost vertical right bank, and a less steeply inclined left bank (see Figure 2-3). The combination of the dam and the topography will create a reservoir about 810 meters long (about 46.5 m wide near the dam, then tapering to the west), with an area of about 0.046 km^2 (see Figure 2-4). Given the cross-section of the gorge at the dam site, most of the flooded area (about 70%) will be on the left bank (between the Nikachhu and the national highway), rather than on the National Park side of the river (the right bank).

Figure 2-2: Typical concrete gravity diversion dam (at Dagachhu).

Figure 2-3: Slope conditions at the proposed Nikachhu dam site.

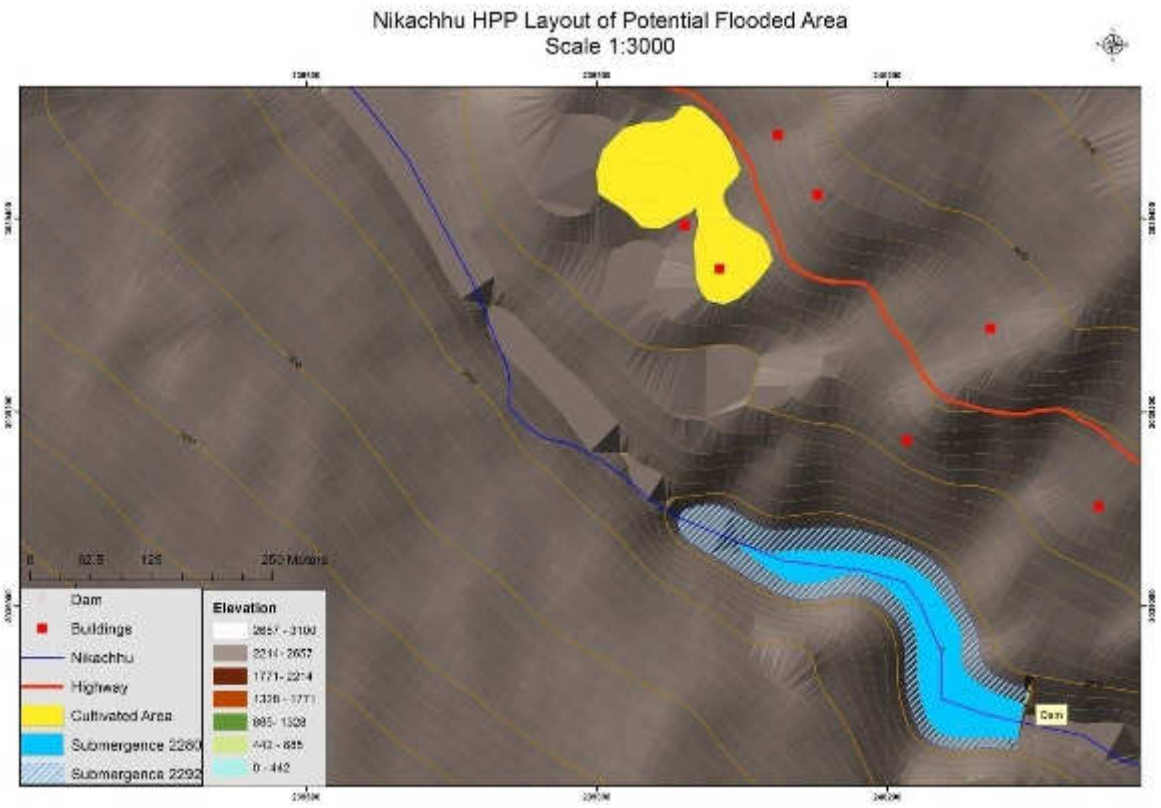


Figure 2-4: Potential flooded area above the Nikachhu diversion dam.

2.4.2 Coffer Dam and Diversion Tunnel

During construction of the dam, the river will be diverted, using a diversion tunnel (see Figure 2-5 for a typical example). Coffer dams (both upstream and downstream) will be required to keep the construction sites dry, to avoid hampering the construction progress and to ensure the safety of the site against flooding. For the design of the diversion tunnel, a 1-in-25 year flood was considered. The dimensions of the coffer dam and diversion tunnel at D2 are shown in Table 2-2. The total length of the diversion will be about 170 m, with a drop of about 6 m over that distance (a slope of about 4%, which is manageable for fish).

Table 2-3: Dimensions of the coffer dam and diversion tunnel.

Feature	Technical Details
Diversion Discharge	80 m^3/s
Diversion on River Bank	Right
Upstream Cofferdam	
Type	Rockfill type with Central
Top of Dam Level	EL. 2,273.50 masl
River Bed Level	EL. 2,266.00 masl
Cutoff for Seepage	2.0 m below bed rock

Feature	Technical Details
Top Width	3m
Top Length	23.21 m
Bottom Width at River Bed	40.5 m
Downstream Cofferdam	
Type	Rockfill type with Central
Top of Dam Level	EL. 2,264.00 masl
River Bed Level	EL. 2,260.00 masl
Cutoff for Seepage	2.0 m below bed rock
Top Width	3 m
Top Length	44.97 m
Bottom Width	19.50 m
Diversion Tunnel	
Width	4.0 m
Shape	D shaped
Length	147.92 m
Lining	0.25 m
Intake Level	EL. 2,266 masl
Outlet Level	EL. 2,262 masl

Figure 2-5: Typical cofferdam and diversion tunnel (at Dagachhu).

2.4.3 Intake and De-silting Chamber

To take advantage of the good topography at the dam site, the power intake has been proposed as a “side” intake type (see Figure 2-5, for an example). Side intakes are the best option in sediment laden rivers. Considering a velocity of 1 m/s and additional flow of 10% for flushing of silt, the

dimensions of the intake and the de-silting chamber are shown in Table 2-3**.** The de-silting chamber will allow deposition of finer sediments, so that they do not go into the powerhouse and turbines. These deposited sediments will be evacuated from the chamber as required (see Figure 2-6 for an example of a de-silting chamber).

Table 2-4: Dimensions of the intake and de-silting chamber.

Feature	Technical Details
Intake	
Full reservoir Level	EL. 2,292 masl
Design discharge	25.45 m^3/sec
Top of intake structure	2,295 masl
Size of the HRT	4.0 m
Invert level of the intake	2275 masl
Intake gate size	4.0 m x 4.0 m (WxH)
De-silting chamber	
Number of de- silting chambers	2
Width	7 m
Height of dome	3.75 m
Vertical height	4.5 m
Height of hoppers	2.75 m
Total height of chambers	10.95 m
Velocity of flow in the chambers	0.25 m/s
Length of the horizontal portion of de-silting	175.0 m
length of upstream transition	20.0 m
Inlet gate	2.0 m x 4.0 m (WxH)
Outlet gate	2.0 m x 4.0 m (WxH)

Figure 2-6: De-silting facility under construction at Dagachhu.

2.4.4 Head Race Tunnel

The diameter of the head race tunnel (HRT) will be 4 m, over a length of 12.144 km. The maximum velocity of water flow in the tunnel will be 1.96 m/s (see Figure 2-7 for an example of a head race tunnel). Construction of the HRT will require five adits and associated access roads and muck disposal areas. The four associated access roads will be taken off from the national highway, and muck disposal from the adits will be undertaken adjacent to the access roads. Muck disposal sites will be re-vegetated once the construction work is complete.

Figure 2-7: Head race tunnel at Dagachhu.

2.4.5 Surge Shaft

The diameter of the surge shaft will be 10.5 m and the height will be 57.2 m (see Figure 2-8 for an example of a surge shaft). The top elevation of the surge shaft will be at 2,319.7 masl. The surge shaft will be located at the end of the tail race tunnel, near the powerhouse at Norbuodi (see Figure 2-9).

Figure 2-8: The surge shaft under construction at the Dagachhu site.

Figure 2-9: The proposed location of the surge shaft at Norbuodi.

2.4.6 Pressure Shaft

A vertical drop pressure shaft has been proposed. The dimensions of the pressure shaft are noted in Table 2-1.

2.4.7 Powerhouse

Due to unfavorable topography at Norbuodi for a surface powerhouse, an underground powerhouse has been proposed, which will require a main tunnel as an access during construction, as well as

during operation. The powerhouse cavern will measure 66.67 m (length) x 19 m (width) x 41 m (height); see Figure 2-10 for an example (Dagachhu). The transformer cavern will measure 61 m (length) x 14 m (width) x 27.1 m (height).

Figure 2-10: The powerhouse under construction at Dagachhu; Nikachhu will have a similar configuration.

2.4.8 Tail Race Tunnel

The diameter of the tail race tunnel will be 4 m. The length will be 443 m. The tail race will discharge to the reservoir area above the Mangdechhu diversion dam (a cascading scheme), adding power potential to that project.

2.4.9 Main Access Tunnel and Adits

The Main Access Tunnel (MAT) will be 7 m in diameter. It will be a D-shaped tunnel, with a distance to the powerhouse of 553 m. The length of all adits is summarized in the Table 2-4. Adits 1-5 are required for construction of the head race tunnel. Their locations are shown in Figure 2-11. Additional adits are being considered for the de-silting chamber, pressure shaft, and the TRT (total length of 1,032 m).

Table 2-5: Length of confirmed Nikachhu adits.

ADIT	Length (m)
ADIT-1	509.81
ADIT-2	830.74
ADIT-3	523.35

ADIT	Length (m)
ADIT-4	693.95
ADIT-5	791.31
ADIT to surge shaft top	463.00
ADIT to BVC	369.00
Total (m)	**4,181.16**

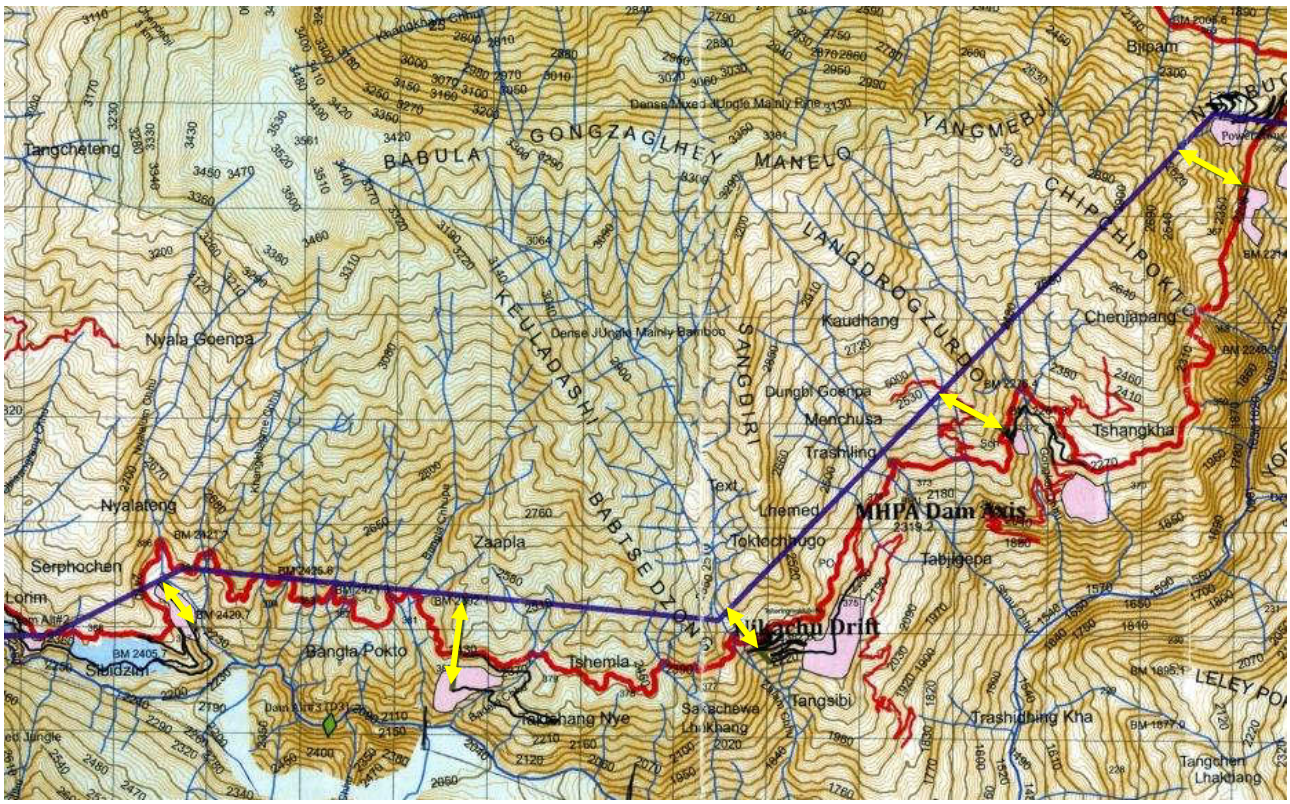


Figure 2-11: Locations of adits (yellow arrows) for the Nikachhu project.

2.4.10 Access Roads

2.4.10.1 Access Road to Dam

An access road of approximately 2.1 km will be required to connect the dam site with the Thimphu-Trashigang National Highway (see Figure 2-12 for locations of proposed access roads). A take-off is proposed along the National Highway at Lorim village, Tangsibji Geog (see Figure 2-13 for a typical example of an access road for a hydropower project in Bhutan). The access road will be on the north side of the Nikachhu, away from the Jigme Singye Wangchuck National Park. All access roads will require forest clearing, slope stabilization, and re-vegetation along the roadside.

Figure 2-12: Locations of proposed access roads (in yellow), muck disposal areas (in pink), and colonies (in blue).

2.4.10.2 Access Road to Surge Shaft

An access road with a length of approximately 1.50 km will be required to connect to the surge shaft area (Adit to BVC and Surge Shaft) at Norbuodi. A take-off is proposed along the National Highway at Chipchipokto, Tangsibji Geog.

2.4.10.3 Access to Power House

The powerhouse will be approximately 300 m upstream of the Mangdechhu dam. The access road facilities constructed for the Mangdechhu Hydropower Project will be used as access to the Nikachhu powerhouse. However, an additional road length of 5.7 km shall be constructred from National Highway to connect Power House Complex and Mangdechhu Dam.

2.4.10.4 Access Roads to Adits

There will be five adits, and all required access roads will be taken off the existing national highway. The total length of access roads for the adits will be 7.11 km.

2.4.10.5 Access Road Summary

All required access roads are summarized in Table 2-5. Detailed information on the access roads, based on Sectoral Guideline for Highway & Roads-2004 and Guideline 2012, is attached as **Annex A.**

Table 2-6: Summary of access road requirements.

Sl. No	Description	Length	Village	Locations	
				Take-off	Termination point
1	Access Road to Dam Complex from NH2	2.100	Lorim	90°22'21.644"E 27°27'5.512"N	90°22'22.172"E 27°26'55.415"N
2	Access Road to Adit-1 from NH2	2.278	Nyla	90°23'11.901"E 27°26'56.919"N	90°23'26.458"E 27°26'59.718"N
3	Access Road to Adit-2 from NH2	1.973	Zapla	90°24'52.422"E 27°26'52.865"N	90°24'48.676"E 27°26'42.483"N
4	Access Road to Adit-3 from NH2	1.943	Tangsibji	90°27'45.973"E 27°27'57.731"N	90°27'49.284"E 27°27'57.018"N
5	Access Road to Adit-4 from NH2	0.577	Tsangkha	90°27'45.88"E 27°27'57.703"N	90°27'49.317"E 27°27'56.949"N
6	Access Road to Adit-5 from NH2	0.417	Norbuodi	90°28'51.5"E 27°28'42.224"N	90°28'55.448"E 27°28'46.593"N
7	Access Road to Adit to BVC and Surge Shaft top from NH2	1.500	Norbuodi	90°29'10.644"E 27°29'25.744"N	90°28'52.053"E 27°29'29.576"N
8	Access Road to Power House Complex from NH2	5.700	Norbuodi opposite Chenjapang	90°29'8.994"E 27°29'24.413"N	90°29'34.417"E 27°29'16.793"N
TOTAI LENGTH		**16.488**			

Figure 2-13: Typical access road for a hydropower project (Dagachhu project).

Figure 2-14: Transmission lines at Dagachhu.

2.4.11 Transmission Line and Power Evacuation

The power from the NHPP will be evacuated through a double circuit 132 KV transmission line to the Mangdechhu 400/13F2 kV, 200 MVA ICT station at Yurmo in Langthel Geog, Trongsa for an example of local transmission lines). Further evacuation to India shall be through the Mangdechhu HP (720 MW) transmission lines. The tentative length of transmission line from the NHPP powerhouse to the Mangdechhu HPP Pothead yard is about 18.6 km. Installation of this transmission line will involve clearing within the line right-of-way.

The transmission line and power evacuation system for the Nikachhu Project shall be awarded to Bhutan Power Corporation (BPC) as a deposit work during the construction phase from the year 2015-2018. The detail of Transmission Line for Power Evacuation as per Application for Environment Clearacne-Guideline for Transmission and Distribution Line, 2004 is appended as **Annex B** along with Terms of Reference to carry out ESIA for review and endorsement by your oddice. The detailed ESIA shall be prepared as per directive of NEC based on the review of current information and document.

2.5 Project Ancillaries

The Nikachhu project will require ancillary structures to facilitate construction and operation of the project. These include the residential complex, non-residential complex, contractor facility and establishment, warehouse, workshops, muck disposal sites, and explosive magazines. The details concerning the number of housing units, plinth area and land area required for the ancillary

structures as per the DPR are elaborated below. None of these facilities will be located closer than 30 m from watercourses.

2.5.1 Residential Accommodation

The total number of buildings required is 27, of which 10 shall be permanent and 17 temporary. The total plinth area required is 9,733 m². Considering additional area for offsets (40%), internal colony roads, parking area and open space, the total area required is approximately 5.85 acres (2.34 ha).

A list of residential buildings to accommodate staff during the peak construction period and Operation and Maintenance (O&M) period along with the plinth area requirement and total area requirement is shown below:

Table 2.7: Plinth Area of Residential Buildings.

Sl. No.	Description	No. of officers/ staff		No of Units		Plinth Area per Unit	Total Plinth Area (m²)			No. of Buildings		Type
		Peak	O&M	P	T	(m²)	P	T	Total	P	T	
1	CEO (Type -VI (S))	1	1	1	0	213	213	0	213	1	0	Duplex
2	Deputy CEO/ Chiefs	2	0	0	2	160	0	320	320	0	2	
3	EE/ SPO/SFO/ Geologist - (Type - V)	9	4	2	2	140	560	840	1,400	1	3	Double Storey
4	AEE/AE/FO/ Company Secretary/ Manager (Type – IV)	18	6	2	2	100	800	1,000	1,800	2	5	Double Storey
5	AM/JE/LO/IT - (Type-III)	15	11	4	4	85	680	680	1,360	1	2	Double Storey
6	Accountant/ Store In-charge/ Supervisor/ Foreman/Office Assistant/Driver (Type-II)	29	32	4	0	70	2240	0	2,240	3	0	2 nos. of 3 storied and 1 no. 2 storied
7	Casual staff accommodation	6	13	4	0	50	800	0	800	2	0	Double Storey
8	Temporary/casual staff Field Hostel	24		0	8	40	0	960	960	0	3	
9	Temporary/casual staff Shared accommodation in twin sharing basis	16		0	8	40	0	640	640	0	2	
Total		120	67				5,293	4,440	9,733	10	17	
Total permanent Buildings					10	5,293	m²					

Sl. No.	Description	No. of officers/ staff		No of Units		Plinth Area per Unit	Total Plinth Area (m^2)			No. of Buildings		Type
		Peak	O&M	P	T	(m^2)	P	T	Total	P	T	
Total Temporary Buildings					17	4,440	m^2					
GRAND TOTAL					**27**	**9,733**	**m^2**					

Table 2.8: Area required for residential buildings.

Description	Required Land Area	
	m^2	Acres
Plinth area as per Table 2.7.	9,777.00	2.42
Additional 40% for site development and offsets	3,910.80	0.97
Internal colony roads	7,000.00	1.73
Open space	2,500.00	0.62
Parking area	490.00	0.12
Total	**23,677.80**	**5.85**

2.5.2 Non-Residential Complexes

Generally, the non-residential building for hydropower projects comprises a main administrative block, transit camp, recreational club, check post, basic health unit, water treatment plant, DG Building, etc. However, in the case of the Nikachhu HPP, since most of the major works will be implemented through EPC Contract, the non-residential complexes have been planned to meet the basic requirements as detailed below. An additional 60% area on the total plinth area has been considered to estimate the total land area.

Table 2.9: Plinth and land area requirement for non-residential complex at dam site.

Sl. No.	Description/Type	No.	Plinth Area (m^2)	Total plinth Area (m^2)	Total Area incl. site development (acre)	Type
1	Dam site office	1	800.00	800.00	0.32	Temporary (Single Storey)
2	Transit Camp cum Canteen	1	400.00	400.00	0.14	Temporary (Single Storey)

Sl. No.	Description/Type	No.	Plinth Area (m^2)	Total plinth Area (m^2)	Total Area incl. site development (acre)	Type
3	Fire Station	1	150.00	150.00	0.06	Permanent (Single Storey)
4	Water Treatment Plant and supply route	1	2,300.00	2,300.00	0.80	Permanent
5	Sub-station	1	400.00	400.00	0.14	Permanent
6	Check Post	1	50.00	50.00	0.02	Temporary
Permanent Building				2,850.00	1.00	
Temporary Building				1,250.00	0.48	
Total Area				4,100.00	1.48	

Table 2.10: Plinth and land area requirement for non-residential complex at the Powerhouse.

Sl. No.	Description/Type	No	Plinth Area (m^2)	Total Area (m^2)	Total Area incl. site development (Acre)	Type
1	Administrative Office	1	1,500.00	3,000.00	1.19	Permanent (Double Storey)
2	Guest House/Transit Camp	1	1,200.00	1,200.00	0.48	Permanent (Single Storey)
3	Recreational Club	1	500.00	500.00	0.18	Temporary (Single Storey)
4	DG Building	1	200.00	200.00	0.07	Permanent (Single Storey)
5	Fire Station	1	150.00	150.00	0.06	Permanent (Single Storey)
6	Sub-station	1	400.00	400.00	0.14	Temporary
7	Site Office	1	1,000.00	1,000.00	0.35	Temporary (Single Storey)

Sl. No.	Description/Type	No	Plinth Area (m²)	Total Area (m²)	Total Area incl. site development (Acre)	Type
8	Check Post	5	50.00	250.00	0.09	Temporary
9	Water Treatment Plant and supply route	1	800.00	800.00	0.28	Permanent
Permanent Building				5,350.00	2.08	
Temporary Building				2,150.00	0.76	
Total Area				7,500.00	2.84	

Table 2.11: Plinth and land area requirement for non-residential complex at Surge Shaft.

Sl. No.	Description	No.	Plinth Area (m²)	Total Area (m²)	Total Area incl. site development (acre)	Type
1	Site Office	1	500.00	500.00	0.18	Temporary (Single Storey)
2	Sub-station	1	300.00	300.00	0.11	Temporary
			Total	800.00	0.29	

Only temporary non-residential building is planned at the surge shaft, with a total plinth area of 800 m². To accommodate the non-residential building, a total land area of 0.29 acres (0.12 ha) is required.

2.5.3 Construction Facility and Contractor Establishment

The EPC contractors will require space to build their site offices, colonies for their regular employees, labour camps at various sites, stores/warehouse, workshops, parking yards for equipment, fabrication yard, etc. The civil contractors will be required to set up a crushing and aggregate processing plant, batching and mixing plant, material stock piling yards, etc. The E&M contractors will require setting up stores and space for siding of permanent equipment. Adequate space has been earmarked at different project locations to create the above said facilities for the contractors as given in Table 2.12.

Table 2.12: Construction facility and contractor establishment.

Sl. No.	Description/Type	Area for Contractor's establishment in acres							
		Dam	Adit - 1	Adit - 2	Adit - 3	Adit - 4	Adit - 5	Surge Shaft area	Power House area
1	Crusher (100 TPH)	4.0			4	1.5			3
2	Batching Plant (60 & 30 m³/h)	3.0		1.5	1.5			1.5	1.5
3	Explosive Magazine	1.0	0.05	0.05	0.05		0.05	0.05	1
4	Site Office	0.8		0.1	0.1	0.1	0.1	0.1	0.8
5	Labour Camps	2.9	0.5	0.5	0.5	0.5	0.5	0.5	2.9
6	Workshop	1.0							1
7	Godown/Store	1.5	0.15	0.15	0.15	0.15	0.15	1	2
8	Fabrication Workshop for H&M	0.4							0.4
9	Fire Station	0.2							0.2
10	Quality Control Laboratory	0.2							0.2
11	DG Building	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2
12	Transit Camp for Officers	0.5							0.5
13	Water Supply	0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.2
14	Substation		0.05	0.05	0.05	0.05	0.05	0.05	
15	Ferrule/ Hydromechanical workshop							2	
16	Stocking yard								1.69
	Total (a)	**15.9**	**0.9**	**2.5**	**6.5**	**2.5**	**1.0**	**5.4**	**15.6**

The picture below shows the Contractor's facility at the dam site of the Dagachhu Hydropower Project as an example.

Figure 2-15: Contractor's facilities and labour camps.

2.5.4 Muck Disposal Area

As part of the DPR survey and investigation, twelve muck disposal sites located within the project area have been identified, as shown in the table below.

Table 2.13: Identified Muck Disposal Sites.

Muck Disposal Area	Locations	Area m^2
Disposal site- I	Upstream of dam	44,605.00
Disposal site- II	Downstream of dam	23,373.00
Disposal site- III	Near Silt Flushing Tunnel	46,990.00
Disposal site-IV	Adit -1	55,958.00
Disposal site- V	Adit -2	72,996.00
Disposal site- VI	Adit – 3	83,055.00
Disposal site- VII	Aidt – 4	29,303.00
Disposal site- VIII	Common disposal site at Tsangkha	73,116.00
Disposal site- IX	Adit- 5	51,631.00
Disposal site- X	Surge Shaft area	41,198.00
Disposal site- XI	Pressure Shaft area	16,593.00
Disposal site- XII	Power House area	71,000.00
	Total	***609,818.00***

The maps showing the muck disposal area are attached as **Annex-C.**

2.5.5 Muck Generation

The estimated quantity of muck that will be generated from different project construction activities and the corresponding dumping site indicated against respective work sites is as detailed below.

Table 2.14: Quantity of muck and disposal sites.

Sl. No.	Description	Volume of Muck from each work site (m^3)	Identified Muck Disposal Sites	Volume of Muck (m^3)	Available Capacity of Disposal Sites (m^3)
1	Diversion Tunnel	6,357.90	Disposal site - I and II	197,273.03	339,890.00
2	Dam	156,815.43			
3	Inlet Tunnel	9,124.90			
4	GOC	24,974.80			
5	Desilting Chamber	68,796.00	Disposal site – III	87,191.23	197,358.00
6	SFT	6,714.73			
7	ADIT to Desilting	11,680.50			
8	ADIT-1	19,048.18	Disposal site IV	87,919.18	167,874.00
9	In HRT from Adit-1	68,871.00			
10	ADIT-2	27,965.50	Disposal site – V	94,007.50	182, 490.00
11	In HRT from Adit-2	66,042.00			
12	ADIT-3	21,692.70	Disposal site – VI	92,484.70	199,332.00
13	In HRT from Adit-3	70,792.00			
14	ADIT-4	25,041.98	Disposal site - VII & VIII	102,127.98	204,838.00
15	In HRT from Adit-4	77,086.00			
16	Adit-5	27,777.80	Disposal site – ix	76,904.80	154,893.00
17	In HRT from Adit-5	49,127.00			
18	ADIT to Surgeshaft Top	14,809.43	Disposal site- X	42,221.52	123,594.00
19	ADIT to BVC	12,682.02			
20	Surge shaft	9,685.78			

Sl. No.	Description	Volume of Muck from each work site (m^3)	Identified Muck Disposal Sites	Volume of Muck (m^3)	Available Capacity of Disposal Sites (m^3)
21	Butterfly valve chamber	5,044.29			
22	ADIT to Pressure Shaft	18,481.66		27,309.07	53,097.00
23	Pressure shaft	8,827.41	Disposal site – XI		
24	Power house cavern	60,353.95			
25	Main access tunnel	22,806.22			
26	Tail race tunnel	14,766.11			
27	ADIT to TRT	9,972.82			
28	ADIT to Control Room cum Ventilation Tunnel	44,874.08	Disposal site – XII	184,105.10	213,000.00
29	Transformer cavern	24,307.05			
30	Ventilation tunnel, cat	7,024.87			
31	Site office, residential , non - residential and contractors facilities at Dam area	45,060.74	Disposal site - I and II	45,060.74	142,616.97
32	Contractors facilities at Adit -1	364.22	Disposal site – IV	364.22	79,954.82
33	Contractors facilities at Adit -2	1,011.72	Disposal site- V	1,011.72	88,482.50
34	Contractors facilities at Adit -3	2,630.46	Disposal site- VI	2,630.46	106,847.30
35	Contractors facilities at Adit -4	991.48	Disposal site- VII & VIII	991.48	102,710.02
36	Contractors facilities at Adit -5	404.69	Disposal site- IX	404.69	77,988.20
37	Non - Residential And Contractors Facilities at Dam area	5,365.07	Disposal site – X	5,365.07	81,372.48

Sl. No.	Description	Volume of Muck from each work site (m^3)	Identified Muck Disposal Sites	Volume of Muck (m^3)	Available Capacity of Disposal Sites (m^3)
38	Site office, residential, non - residential and contractors facilities at Power House area	54,445.40	Disposal site- X,XI & XII	54,445.40	179,849.82
39	Road to Dam Complex	76,257.80	Disposal site I & II	76,257.80	97,556.23
40	Road to Adit 1	64,994.90	Disposal site IV	64,994.90	79,590.60
41	Road to Adit 2	41,296.40	Disposal site V	41,296.40	87,470.79
42	Road to Adit 3	48,809.10	Disposal site VI	48,809.10	104,216,84
43	Road to Adit 4	10,269.00	Disposal site VII	10,269.00	101,718.51
44	Road to Adit 5	8,487.52	Disposal site IX	8,487.52	77,583.51
45	Road to BVC and Surge Shaft top	35,568.66	Disposal site X	35,568.66	76,007.41
46	Road to Power House Complex	127,378.22	Disposal site XI & XII	127,378.22	128,115.99
Total estimated muck		**1,514,879.48**			

2.6 Land Area Required for the Project

Table 2-15: Land requirements for project ancillaries.

Sl.No.	Component	Description	Area (Acre)	Total (Acre)	Permanent	Temporary
1	Dam	Residential Complex	4	49.42	3	1
		Non-Residential Complex	2.77		1.96	0.81
		Reservoir Area	12.28		12.28	0
		Contractor Facility and Establishment	15.8		0	15.8
		Muck Disposal	10.03		0	10.03
		Access Road	4.54		4.54	0
2	Power House	Residential Complex	2.00	54.9	2.00	0
		Non-Residential Complex	2.63		2.1	0.53
		Contractor Facility and	16.59		0	16.59

Sl.No.	Component	Description	Area (Acre)	Total (Acre)	Permanent	Temporary
		Establishment				
		Muck Disposal	17.54		0	17.54
		Access Road	18.14		18.14	0
3	Surge Shaft & BVC	Residential Complex	0.00	19.72		
		Non-Residential Complex	0.91			0.91
		Contractor Facility and Establishment	4.5			4.5
		Muck Disposal	10.18			10.18
		Access Road	4.13		4.13	
4	**HRT and ADITs**					
	ADIT - 1	Contractor Facility and Establishment	0.9	19.95		0.9
		Muck Disposal	13.82			13.82
		Access Road	5.23			5.23
	ADIT - 2	Contractor Facility and Establishment	2.5	24.99		2.5
		Muck Disposal	18.04			18.04
		Access Road	4.45			4.45
	ADIT - 3	Contractor Facility and Establishment	6.5	32.18		6.5
		Muck Disposal	20.52			20.52
		Access Road	5.16			5.16
	ADIT - 4	Contractor Facility and Establishment	2.5	11.2		2.5
		Muck Disposal	7.2			7.2
		Access Road	1.5			1.5
	ADIT - 5	Contractor Facility and Establishment	4.5	18.05		4.5
		Muck Disposal	12.76			12.76
		Access Road	0.79			0.79
5	ADIT to Pressure Shaft	Muck Disposal	4.1	23.28		4.1
		Access Road	1.11			1.11
6	Common Muck Disposal	Muck Disposal	18.07			18.07

Sl.No.	Component	Description	Area (Acre)	Total (Acre)	Permanent	Temporary
Total Area Required (in acres)				**253.69**	**46.15**	**207.54**
Total					**253.69 (101.5 ha)**	

The Contrators' Facilities and Establishment in the above table comprises the Hydro-mechanical workshop, concrete Batching Plant, Aggregrate Processing Plant, Hot Mix Plant, Explosive Magazines, Warehouse, etc.

Except for 3.57 acres (1.43 ha) of private land affected by project roads and dam colony, all the other project components and facilities will be located in State Reserved Forest (SRF) land. The impacts on private lands by the project have been assessed based on a detailed land demarcation survey carried out by Trongsa Dzongkhag in close coordination with DGPC. While carrying out the survey, it was found that there was no private land holding within the 30 m buffer distance from the reservoir.

2.7 Construction Power Requirements

The electricity requirement of the NHPP (its construction) is expected to be about 5,450 kVA or 5.45 MW. The details are noted in Table 2-16 below.

Table 2-16: Construction power requirements.

Locations	Machinery Required	Total kVA
Dam Site: For Dam, Intake, De-silting Chambers, HRT Adit, Crushing Plant, Batching and Mixing Plant, Workshop, Testing Laboratory.	Crawler drill, Boom Drill Jumbo, Hydraulic Excavator, Rear Dumpers, Grout pumps, Rail Mounted Tower Crane, Batching and Mixing Plant, Aggregate Crushing Plant, Chilling Plant, Air Compressor, Dewatering Pump, Diamond Core Drill, Triplex Pump, Pneumatic Sump Pump, Water Sprinkler, Dozer with Ripper Attachment, Ice Plant, Rock Bolting Machine, Shotcreting Machine and Front and End Loader.	1,500
HRT: Including Adits, Batching and Mixing Plant.	Same as in 1.	1,500
Surge Shaft and BFV Chamber	Boom Drill Jumbo, Front End Loader, Air Compressor, Pilot Hole Driller, Raise Bore, Pilot Shaft Driller, Dumper, Rock Bolting Machine, Shotcreting Machine, Batching and Mixing Plant, Transit Mixer, Grout Pumps, Excavator, Crawler	750

Locations	Machinery Required	Total kVA
	Driller etc.	
Pressure Shaft	Same as above.	500
Power House Complex: Including Adits, Batching and Mixing Plants.	Same as above.	1,000
Tailrace Tunnel: Including Adits, Batching & Mixing Plant.		315
Batching Plants		315
Colonies, Labour Camps, Hospital, School: For all Civil, H&M and E&M packages, including contractor's colony.		750
Workshop		750
Total (kVA)		**7,380 kVA or 5,904 kW**

To meet the construction power requirement for construction activities, it shall require extension of 5km, 33 kV Transmission Line from Banglapokto till the work site and stepping it down from 33 kV to 0.415kV supply source to for construction of Nikachhu Hydropower Project at Dam and Adit-I & II. The power requirement for Power House, Surge Shaft and Adits III-V shall be met from the existing power grid available. This will not require any extension of power lines.

The detailed information for construction of 5 km, 33 kV Construction Power for Niakchhu Hydropower Project as per Sectoral Guideline for Transmission Lines, 2004 is provided in **Annex-D** along with statutory clearances.

2.8 Water Supply System

During the construction of the project, water will be required for the following main purposes;

i. Drinking and washing by the laborers;
ii. Sprinkling on the roads to suppress dust;
iii. During construction, involving drilling, grouting, shotcreting, concreting and curing.

i. Water utilization for drinking and washing

It is estimated that about 2,000 workers will be deployed at various locations during the peak construction period. According to the World Health Organization (WHO), 50 to 100 litres of water

per person per day is needed to ensure that most basic needs are met and few health concerns arise. Accordingly, the water requirement at each location for drinking and washing is given in Table

Table 2-17: Estimated water requirement at each location.

Sl. No.	Locations	No. of workers	Water Requirement (litres/sec)
1	Dam area icluding Coffer Dam and Diversion Tunnel	200	0.116
2	Intake	50	0.029
3	Desilting Chamber	150	0.087
4	Adit 1 and HRT	200	0.116
5	Adit 2 and HRT	200	0.116
6	Adit 3 and HRT	200	0.116
7	Adit 4 and HRT	200	0.116
8	Adit 5 and HRT	200	0.116
9	Surge Shaft	150	0.087
10	Pressure Shaft	150	0.087
11	Power House, TRT	300	0.174
	Total	**2,000.00**	**1.157**

ii. Water utilization for sprinkling on roads to suppress dust

It is proposed to use the water tanker of 10,000 litres capacity at various project sites to reduce the dust. The estimated water requirement at each location is given in Table 2.18.

Table 2-18: Water requirement for sprinkling on roads.

Sl. No.	Locations	Length of Road (km)	No. of times in a day	No. of Tankers	Water Requirement (litres/sec)
1	Dam Complex	2.1	2	1	0.231
2	Adit 1 and HRT	2.278	2	1	0.231
3	Adit 2 and HRT	1.973	2	1	0.231

Sl. No.	Locations	Length of Road (km)	No. of times in a day	No. of Tankers	Water Requirement (litres/sec)
4	Adit 3 and HRT	1.943	2	1	0.231
5	Adit 4 and HRT	0.577	1	1	0.116
6	Adit 5 and HRT	0.417	1	1	0.116
7	Surge Shaft	1.5	2	1	0.231
9	Power House complex	5.9	2	1	0.231

iii. Water utilization during construction involving drilling, grouting, shotcreting, concreting and curing

During the construction stage, water will be required for various activities like drilling, grouting, shotcreting, concreting, curing etc. However, most of the above activities are carried out in sequence, which means the water requirement is not utilized at the same time by all the activities. For example, in the tunnel, the activities like drilling, grouting, shotcreting, concreting and curing are carried out in series during different periods of time. The water utilization by each of the activities in the tunnel has been estimated as given in Table 2-19.

Table 2-19: Water requirement for various activities in the tunnel

Sl. No.	Details	Unit	Values
1	**Boomer M2D for drilling**		
	Pump capacity	litres/min	250
	Water consumption as per specification of the Boomer	litres/s	1.1
	water consumption in two faces	litres/s	2.2
2	**Grouting**		
	Pump capacity asper tech. specs	litres / min	150
	% of water in grout mix	%	85%
	water comsumtion in two faces	litres/s	4.25

Sl. No.	Details	Unit	Values
3	**Shotcreting**		
	Capacity of Shocrete machine as per tech. specs	m^3/hr	16
	Water utilisation for cum of mix	m^3	0.18
	Water utilisation for 2 faces	litres/s	1.6
4	***Concreting***		
	Progress per month as per DPR	m	143
	Progress per day	m	24.00
	Dia. Of tunnel	m	4.50
	Thickness of concrete	mm	300.00
	Quantiy of Concrete per m length	m^3	19.09
	Quantity poured per day	m^3	458.04
	W/C ratio		45%
	Cement in one cum of concrete (1:1:2)	m^3	0.25
	Water in 1 cum of Concrete	m^3	0.11
	Water required	litres/s	0.596411730
5	**Curing (in 100% of concreting)**	Litres/s	0.596411730

From Table 2-19, it is seen that the maximum water will be required during grouting compared to other activities and therefore for the purpose of estimation, the water required for grouting will be taken into account.

Similarly, during the construction of the dam, the maximum water will be required during the concreting and curing as given in Table 2.20.

Table 2-20: Water requirement for concreting and curing of dam

Sl. No.	Details	Unit	Values
1	**Concreting of Dam**		
	Capacity of batching machine	m^3/hr	60
	Cement in one cum of concrete	m^3	0.25

Sl. No.	Details	Unit	Values
	W/C ratio (45%)	m^3	0.1125
	Water required per m^3 of concrete	litres	112.50
	Volume of water required	m^3/s	0.001875
2	**Curing (100% of concreting)**	m^3/s	0.001875

iv. Source of water and maximum water utilization

The source of water supply for the dam area, Adit 1, Adit 2 and Adit 3 has been identified from the tributaries of the Nikachhu. For Adit 4, Adit 5 and Surge Shaft, Pressure Shaft and Power House Complex, the water supply source has been indentified from Gongkharchhu which is a tributary of Mangdechhu. The details of source of supply, pipe length and total water requirement from each source is given in Table 2-21.

Table 2-21: Details of water source and % water utilized.

Sl. No.	Components	Source of Supply	Approx. Pipe Length in km for Water Supply	Water require-ment in litres/sec	Minimum water available at source in litres/sec	% of water Utilised
1	Dam & Adit 1	Nyalalumchhu	2.23	5.06	73.46	6.89%
2	Adit 2	Banglachupa	0.25	4.60	66.45	6.92%
3	Adit 3	Zalamchhu	0.41	4.60	121.09	3.80%
4	Adit 4	Gongkhorchhu / Shau Chhu	0.35	4.48		
5	Adit 5	Gongkhorchhu	2.78	4.48		
6	SS and BVC	Gongkhorchhu	1.56	4.57	**84.10**	**21.73%**
7	PS, PH and TRT Area	Gongkhorchhu	1.20	4.74		
	Sl. No. 4+5+6+7			**18.27**		

For Nyalalumchhu and Banglachhu, presently, the water is not used upstream or downstream. The water source for Adit 3 is Zalamchhu. The water from Zalamchhu is presently being used for drinking water for Tansibji village and 30 kW Micro-hydel. For both purposes, water is tapped upstream of the proposed source for Adit 3. The elevation at the Intake of Tangsibji micro-hydel is 2,284.8 m while the invert level of Adit 3 is at 2,230 m which is downstream of intake location of micro-hydel. Similarly, there are no downstream users for Gongkhorchhu.

The water requirement calculated in Table 2.21 is the maximum water required. It is pertinent to mention here that about 50% to 60% of the estimated water requirement for the project will be discharged back to the stream as wastage. From Table 2.21, it is estimated that the water requirement for the project is very minimal and will not have any adverse effect on the stream flow.

2.9 Requirements for Raw Materials/Construction Materials

The construction of the NHPP will require large quantities of materials. These materials include cement, coarse aggregates, sand, and steel. Furthermore, as noted above, a lot of muck, soil, and stone will be generated, due to excavation at the dam site, the powerhouse, the intake, and outfall sites (some of this will be re-used as construction raw material or for site preparation). The steel to be used for the project (a relatively small quantity) will be imported from India, and will be transported via Gelephu or via Phuntsholong-Thimphu-Wangdue (both routes have been widened, and have supported materiel transport for the Mangdechhu project). The raw and construction material estimates are only indicative; at least until final project technical details are confirmed. The expected requirements are summarized in Table 2-22.

Table 2-22: Major Construction Material Requirements.

Item/ Material	Concrete Volume (m^3)	Cement (m^3)	Sand (m^3)	Gravel/ Aggregate (m^3)
Dam	156,289.41	23,443.41	40,635.25	70,330.23
Intake (HRT)	103,653.00	15,547.95	26,949.78	46,643.85
Outfall (TRT)	13,349.25	2,002.39	3,470.81	6,007.1625
Power House & GIS Hall	28,617.11	4,292.57	7,440.45	12,877.70
Total	**301,908.77**	**45,286.32**	**78,496.28**	**135,858.95**

Table 2-10 indicates that about 301,909 m^3 of concrete will be used for construction activities. This will require about 45,286 m^3 of cement, 78,496 m^3 of sand, and 135,859 m^3 of aggregate. The assumptions which have been used to arrive at this quantity of materials are noted below:

1. About 10% of wastage of the raw material will occur during concreting.

2. The ratio of cement to concrete is 15%, sand is 26%, and aggregate is 45%.
3. Dam specifications have been used as follows: crest length is 45 m, width is 5 m; dam foundation depth is expected to be 24 m, and width 16 m; river width is assumed to be 25m.
4. The intake (HRT) width has been taken as 0.5 meters, internal diameter will be 4.5m, it will 13.25 km long; the outfall (TRT) width has been taken as 0.5 meters, and the internal diameter will be 4.5m.
5. Overall powerhouse and transformer cavern dimensions have been taken as 60.85 m x 17 m x 37.4 m and 37.6 m x 16 m x 25.90 m, respectively. The powerhouse and GIS cavern will be divided into two sections, mainly the turbine/generator section and GIS section. The thickness of the wall in both the sections has been assumed to be 2 m.

2.9.1 Borrow area for Clay Material

Two temporary cofferdams have to be constructed as part of the river diversion arrangement to facilitate construction of the main dam. In view of the relatively small size of the river with designed diversion flood of 80 m^3/s, the size of the upstream and downstream cofferdams is also smaller, with a height of only 12.5 m and 5.5 m, respectively. The length of the upstream coffer dam and the downstream coffer dam is 23.21 m and 44.97 m, respectively.

As shown in the Figure 2-16 below, the cofferdam is constructed of compacted rock fill material with an impervious clay core. The total quantity of clay core required is estimated at about 1,757 m^3.

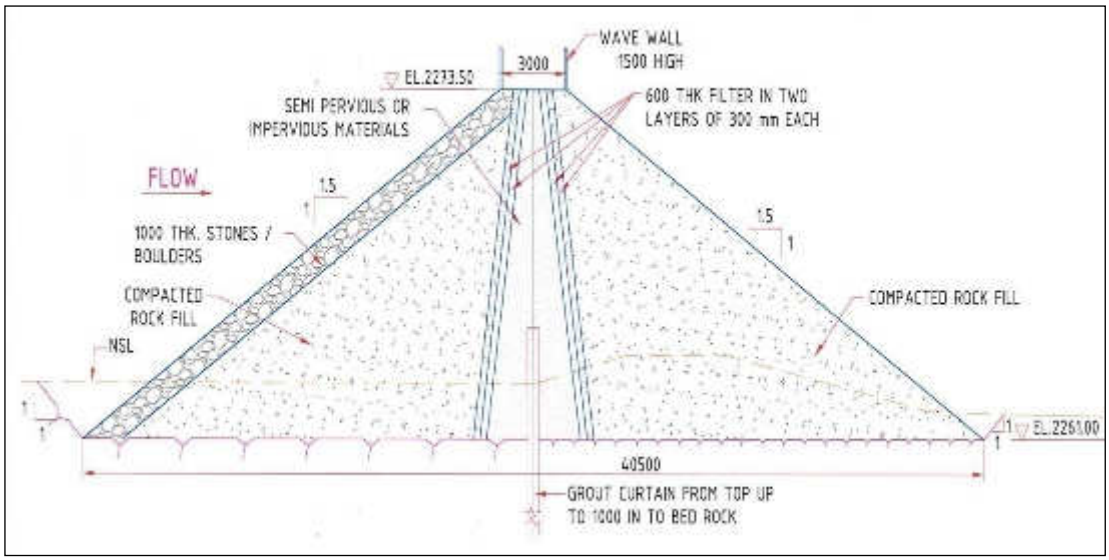


Figure 2-16: Cofferdam with impervious clay core

In total, thirteen (13) test pits with average excavated depths of 3 m (i.e., TP-1 to TP-13) were performed around the project area to explore suitable impervious material for use as the impervious core zone of the cofferdams. The figure below shows the location of test pits identified in the feasibility and DPR stages.

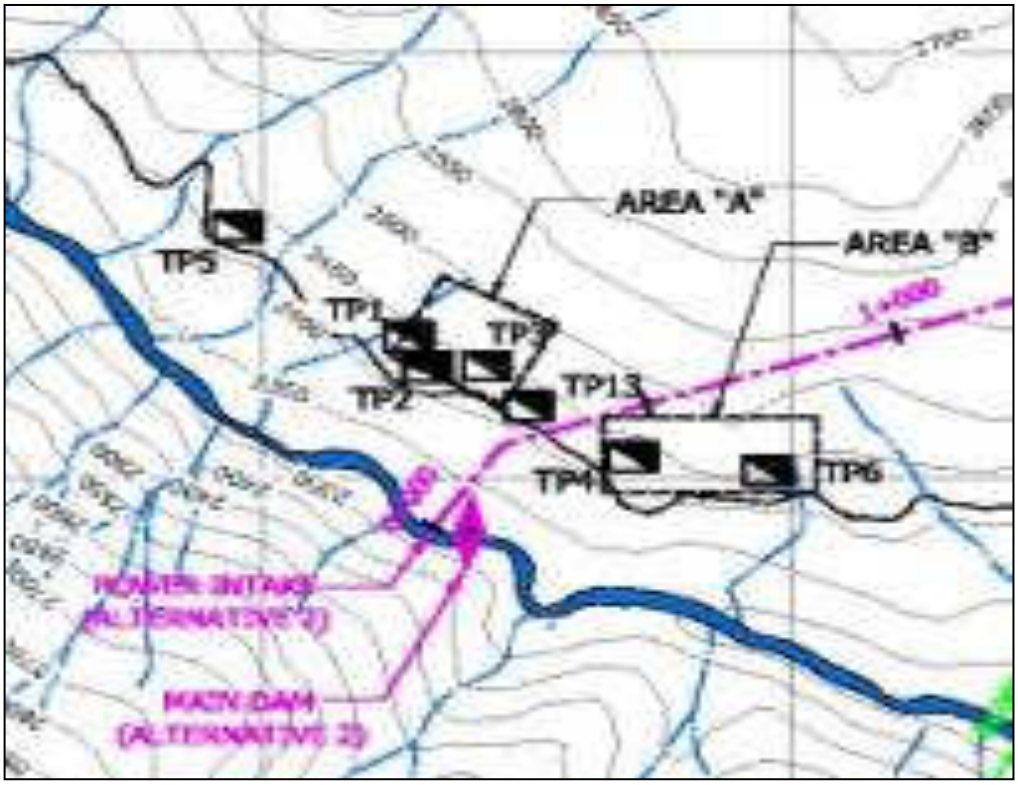


Figure 2-17: Test Pits

Subsurface materials encountered in the test pits are summarized in Table 2-23 below. It is observed that most available soil materials are silty clay/sandy clay and clayey sand/silty sand; they are suitable for use as the impervious core zone for cofferdam construction.

Considering the suitability of materials as well as the accessibility and hauling distance to the dam site, the two most suitable borrow areas for use as impervious core zone for cofferdam construction are proposed as follows:

Area A: It is located on the left bank of the Nikachhu, nearby the main highway with a transportation distance of about 1.5 km from the dam site. The suitable soils are found at a depth of 0.2-3.0 m, generally consisting of Silty Clay (CL). Quantity estimation of available soil material in the area is approximately 100,000 m^3.

Table 2-23: Summary of Test Pit Investigations.

Test Pit No.	Coordinate		Elevation (maSL)	Depth (m)	Thickness of Soil (m)				Parent Rock	Suitability for Impervious Core Zone
	N	E			Silty Clay /Sandy Clay	Clayey Sand/ Clayey Silty	Silty Sand /Sand	HW-CW Rock		
TP1	3,039,332	240,275	2,433	2.90	-	1.0	1.8	-	Mica Schist	NO
TP2	3,039,261	240,311	2,434	3.00	3.0	-	-	-	Mica Schist	YES

Test Pit No.	Coordinate		Elevation (maSL)	Depth (m)	Thickness of Soil (m)				Parent Rock	Suitability for Impervious Core Zone
	N	E			Silty Clay /Sandy Clay	Clayey Sand/ Clayey Silty	Silty Sand /Sand	HW-CW Rock		
TP3	3,039,263	240,423	2,435	3.00	2.2	1.8	-	-	Mica Schist	YES
TP4	3,039,050	240,699	2,427	4.00	3.6	0.4	-	-	Mica Schist	YES
TP5	3,039,590	239,951	2,414	4.30	-	4.3	-	-	Mica Schist	YES
TP6	3,039,018	240,954	2,448	3.00	-	3.0	-	-	Mica Schist	YES
TP7	3,038,982	241,756	2,434	3.00	2.7	0.3	-	-	Mica Schist	YES
TP8	3,039,111	241,796	2,443	3.00	2.6	0.4	-	-	Mica Schist	YES
TP9	3,039,068	243,516	2,428	2.00	0.9	0.2	-	0.9	Mica Schist	YES
TP10	3,039,064	243,625	2,440	3.00	2.6	0.2	-	0.2	Granite	YES
TP11	3,038,930	241,777	2,439	3.00	1.0	0.4	-	1.6	Granite Dyke	YES
TP12	3,038,860	241,904	2,408	3.00	2.3	0.5	-	0.2	Mica Schist	YES
TP13	3,039,169	240,503	2,425	3.50	0.45	-	3.05	-	Mica Schist	NO
			Total	**40.70**	**21.35**	**12.5**	**4.85**	**2.9**	**-**	**-**

Area B: It is located on the left bank of the Nikachhu, nearby the main road, with a transportation distance of about 1.5 km from the dam site. The suitable soils are found at a depth of 0.2-3.0 m, generally consists of Silty Clay (CL) and Clayey Sand (SC). Quantity estimation of available soil material in the area is approximately 120,000 m^3.

As mentioned above, the quantity of clay material required for the temporary cofferdams is very small, which will be met from various borrow areas in the vicinity of the dam site. Therefore, preparation of PIT Plan and EMP is not be necessary.

2.10 Construction Activities and Schedule

Project activities will involve pre-construction activities (such as site preparation and building access roads) and the main construction activities related to the dam, power house and associated structures. These are summarized below.

Pre-construction Activities: All administrative, financial and legal formalities for execution of the project will be completed before start-up of construction activities. It is proposed that construction of most of the access roads, portals, and residential buildings be completed prior to formally taking up the project.

Infrastructure Facilities: Before undertaking construction activities, it is necessary to complete certain infrastructure facilities, including some residential and office buildings, and arrangement of construction power (the 33 kV Banglapokto Feeder will be accessed for the Dam, and Adits I and II after extension about 5 km and the existing 33 kV Nubi Feeder will be accessed for the powerhouse, surge shaft and Adits III to V. The Nubi Feeder will not require any extension.).

Land Acquisition: Two kinds of land acquisition (i.e., permanent and temporary) will be required for the project. Land required for construction of structures, roads, project colonies, stores, and workshops will be acquired on a permanent basis. There will be temporary use of some land for the work areas of the contractors, their camps, and other facilities.

Access Roads: The construction of access roads will be taken up at the earliest, preferably prior to the formal start of the project.

Tenders and Contracts: The contracts for the various packages will be finalized during the pre-construction phase.

Construction Equipment Planning: The requirement for construction equipment has been worked out on the basis of construction work to be carried out at the following sites:

1) Dam site (works related to the diversion tunnel and coffer dams, diversion dam, intakes, feeders, sedimentation chambers, gate chambers, flushing conduits and HRT from the inlet end).
2) HRT adit to the valve chamber, and the downstream end of the HRT, including the pressure shaft).
3) Switchyard, surge shaft (upper & lower chamber).
4) Powerhouse site (including the outlet tunnel and associated works).

Based on the time available for construction and the quantity of work, an indicative list of equipment has been developed. This includes: compressors; compressors (electrical); rock drills; feeder legs; truck jumbos/hydraulic platforms; blasting equipment; drilling accessories; boom hydraulic jumbo with basket (with 11 KV supply); rock bolters; air track; wheel loader with side dump buckets; 20 T dumpers; scoop trams (2 m^3); transit mixers; concrete pumps with spreader; concrete pumps without spreader; concrete distribution system hydraulically operated; shutters for continuous lining along with traveler; wet shotcrete machine with boom; wagon drills (IRCM 341); hydraulic excavators; tyre loaders; 10 T tippers; aggregate processing plant (120 T/hr); aggregate processing plant (250 T/hr); batch and mixing plants; concrete placers; concrete buckets; tower crane (10 T) @ 40 m radius; tower crane (10 T) @ 30m radius; rubber tyred crane (15 T); rubber tyred crane (72 T); rubber tyred crane (8/10 T); dozers (10 T); trailer (70 T); transformers; diesel generator sets (1000 kVA); vent fans (small and large); vent duct dewatering pumps; portal crane

(20 T); crab winches (10 T); electrical winches (20 T); light vehicles; buses; trailers (20 T); survey instruments; JCB loader/backhoe; workshop equipment; garage equipment; fabrication shop equipment; vibrators for concrete; flexible shaft; electrical winches (10 T); hydraulic excavator; portal crane (20 T); tyre-mounted backhoe; raise climber; raise borer; dry shotcrete machines; core drilling machine; road rollers; motor grader; grouting equipment; and, slip form/shutters. Where relevant, the power requirements of this equipment have been noted in Table 2-8.

Construction Methodology: The construction methodology for various sets of work is provided below. This is based on the standard methodology used for constructing hydropower plants, as well as descriptions in the PFR for NHPP.

Diversion Tunnel and River Diversion: The Nikachhu will be diverted through a diversion tunnel by raising coffer dams in the lean season, to facilitate the construction of the dam.

Coffer Dams: The work on the upstream and downstream 7 meter high coffer dams will be undertaken in the lean season.

Diversion Dam: The construction of the diversion dam will be done in four phases. In the first phase, excavation of the diversion tunnel and excavation for the dam down to the bedrock in the river will be undertaken. In the second phase, it is proposed to concrete the dam blocks. In the third phase, the radial gates will be installed and concreted before the onset of the monsoon. The remaining concreting will be done in the fourth phase.

Intake Structure and Feeder Tunnels: Open excavation for the intake structures will be followed by underground excavation for the feeder tunnels. The concreting of the feeder tunnels will be done after completion of the de-silting chamber basins. This will be followed by concreting of the intake structure, followed by erection of the gates and hoists.

De-silting Chambers: The proposed sequence of construction of the de-silting chambers will be as follows:

- The excavation of the roof arch of these chambers will be carried out after completion of excavation of feeder tunnels. First the left half of the crown will be excavated, followed by the right half.
- The excavation of the connection tunnels to the HRT will be then be carried out. The mucking may be done through the flushing tunnel or from the feeder tunnels.
- The excavation of the flushing tunnel and the valve chambers will be sequenced to facilitate the process of muck from the de-silting chambers.
- The excavation will be followed by concreting of the de-silting basins, followed by concreting of the feeder tunnels, valve chambers, flushing tunnel and installation of the valves and

gates in the gate chamber.

Headrace Tunnel: The tunnel will be excavated by a conventional drill and blast method, with access from the adits. Excavation of the HRT will require surveying, blasting, drilling, charging, de-fuming, scaling, mucking, cleaning, shotcreting, erection of ribs, and concreting. Concrete lining of the HRT will be done using a collapsible shutter with traveler and a concrete pump with a concrete distribution system for continuous lining of the tunnel.

Surge Shaft: The surge shaft construction will consist of the upper chamber, the upper riser shaft between the upper and lower chamber, and the lower chamber and lower riser shaft between lower chamber and the HRT. The open excavation for the platform at the top and excavation for the upper chamber will be carried out by using jack hammers, and mucking will be done by winch.

Valve Chamber: Work pertaining to the valve chamber and pressure shafts will be carried out independently from the work related to the HRT.

Pressure Shafts: The excavation of the top horizontal portion of the pressure shafts will be carried out through the adit to the valve chamber. The excavation of the vertical portion of the pressure shafts will be carried out from the bottom using raise climber/borer equipment; widening will be done from top. The erection of penstock liners (ferrules) in the top horizontal portion and in the vertical portion will be carried out through the valve chamber adit, while the erection of ferrules in the bottom horizontal portion will be carried out through the construction adit at the bottom of the penstocks.

Powerhouse Complex: The approach to the powerhouse complex will include construction of a multipurpose access tunnel to the powerhouse, which will also serve as access to the powerhouse tailrace, cableway, and ventilation. The length of this tunnel for NHPP will be 1,500 m.

Powerhouse Cavity: The construction of the powerhouse cavity is the most critical item in the powerhouse complex. The adit at the top of the powerhouse will be used for excavation of the roof arch of the cavity. Similarly, the adit to the transformer hall roof will be used for excavation of the roof arch of the transformer hall and for the downstream expansion chamber. The excavation of roof arch of all cavities will be done by excavating the central drift and then widening the drift, followed by benching to various levels in the powerhouse cavity, the transformer hall, and the expansion chamber. Mucking in the power cavity while benching will be done from the access tunnel, the tailrace ducts, and the adit to the unit penstocks.

Transformer Hall Cavity: The excavation of the roof arch will be carried out through the adit at the top of the transformer hall. The benching down will then be carried out and mucking will be done through the adit to the access tunnel.

Downstream Expansion Chamber: The excavation of the roof arch will be carried out through the adit taking off from the multipurpose tunnel. The benching down of this cavity and also excavation of the draft tubes will be carried out through the tailrace tunnel. After excavation of the tailrace tunnel, a temporary vertical shaft will be excavated through the surge chamber, which will be used for mucking while benching down the expansion chamber.

Cable Tunnel: The cable tunnel will be constructed as an inclined shaft.

Tailrace Tunnel and Outfall Structure: The excavation of the tailrace tunnel will be carried out from the river end (which will be within the Mangdechhu reservoir at that time). Depending on the commissioning and status of the Mangdechhu project, an all season coffer dam may be constructed to isolate the portal from the river. In the initial reach, fore-poling is expected for tunneling, as described in the HRT section. The concreting of the tailrace tunnel will be done after completing all activities related to the expansion chambers. The outlet structure will be constructed during the non-monsoon period, after all the excavation to be carried out from the tailrace tunnel is completed. The commissioning of gates and hoists will follow the concreting of the outlet structures.

A tentative construction schedule is provided in Table 2-24.

Table 2-24: Tentative construction schedule.

Task Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
Feasibility study and ESIA study									
Approval for construction clearance and other applied clearances									
Pre-construction activities (roads and colonies)									
Tendering and award of main package									
Construction									
Commissioning									

2.10 Staffing and Labor Requirements

To achieve the objective of commissioning the project and also to ensure quality of all the works as per technical specifications and standards, an efficient and results-oriented construction organization will be set up. The proposed organization structure will have a built-in mechanism for constant progress review, and monitoring of the works by using management information systems. The computer software for PERT and CPM will be extensively used for overall planning of the project, as well as for day-to-day planning of individual components of the project.

Staffing for the project management required during the construction stage will be recruited on a permanent or contract basis estimated at about 80, excluding security and work charged staff. Post commissioning, suitable staff will be absorbed for operation and maintenance (O&M) of the power plant estimated at about 67.This does not include the staff of the contractors. The construction organization will be headed by a Managing Director (MD). The project organogram during peak construction stage is shown in Figure 2-16. As per this organization among others, the project will have a Technical Division, Environment Wing and Quality Control & Instrumentation Division. The Technical Divisions will be responsible for all works related to civil, electro and hydro-mechanical, infrastructure facilities. The project will be constructed through EPC mode. It is estimated that a workforce of about 2,000 labourers and staff will be deployed by the contractors. Different categories of technical and non-technical staff will be positioned for various activities, depending upon the actual requirements. The design and engineering aspects of the project will be carried out by the design and engineering consultant. A core group of engineers, with experience in investigation, design, construction, and O&M of hydropower projects, will be established at the head office. The broad functions of this core group will be as below:

1) Provide technical support in investigation, analysis of data, and supply of relevant data to the consulting organizations.
2) Technical interaction and coordination with the concerned agencies.
3) Liaison with retained design and engineering consulting organizations and broad checking of their design and construction drawings.
4) Liaison with construction organizations.
5) Modify/revise construction drawings to meet the field conditions.
6) Carry out plant design and other field designs and provide full technical support to the construction organization.
7) Prepare schemes for quality control and inspection and oversee to ensure that the same are executed satisfactorily.

8) Prepare testing and commissioning schedules and O&M manuals in collaboration with the manufacturers of mechanical and electrical equipment. A chart showing the organization setup for the construction stage of the project is shown in Figure 2-17.

The Terms of Reference for Environment Wing/Unit of the project are noted in **Annex-E.**

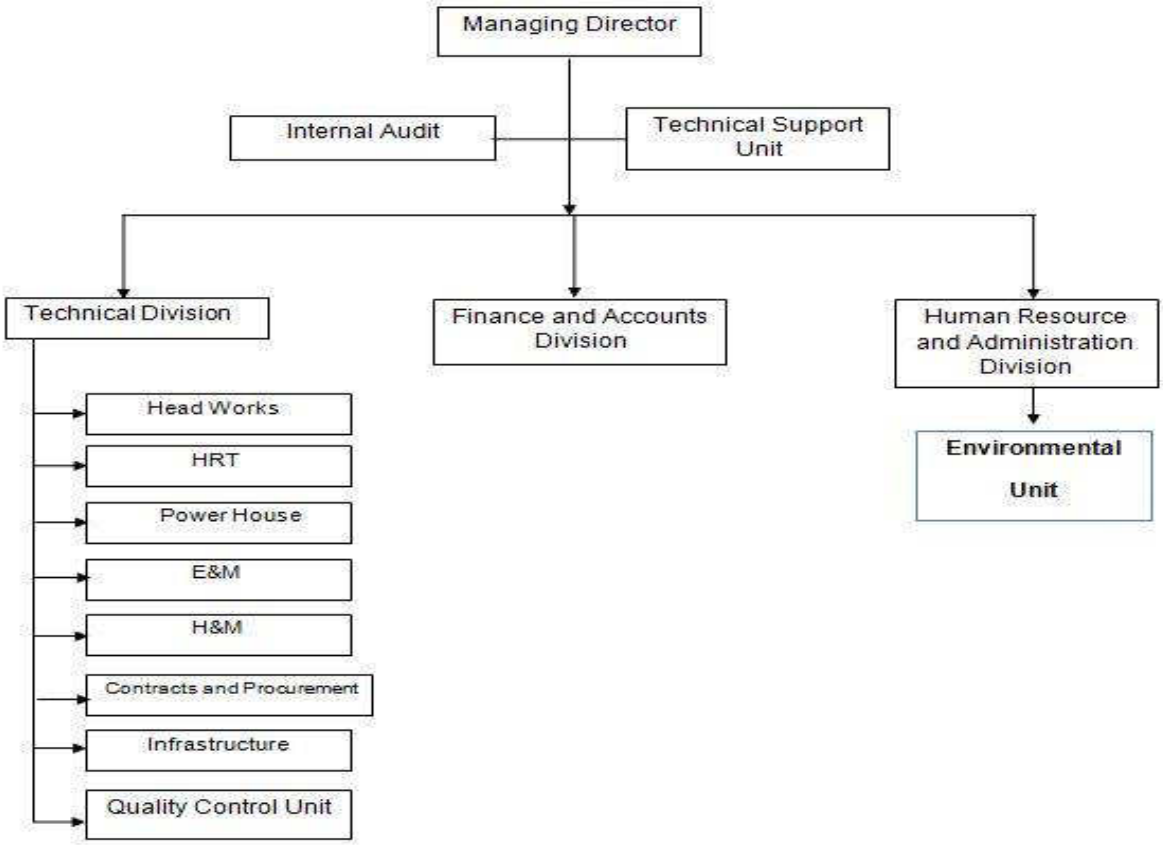


Figure 2-18: Organization structure during the construction stage.

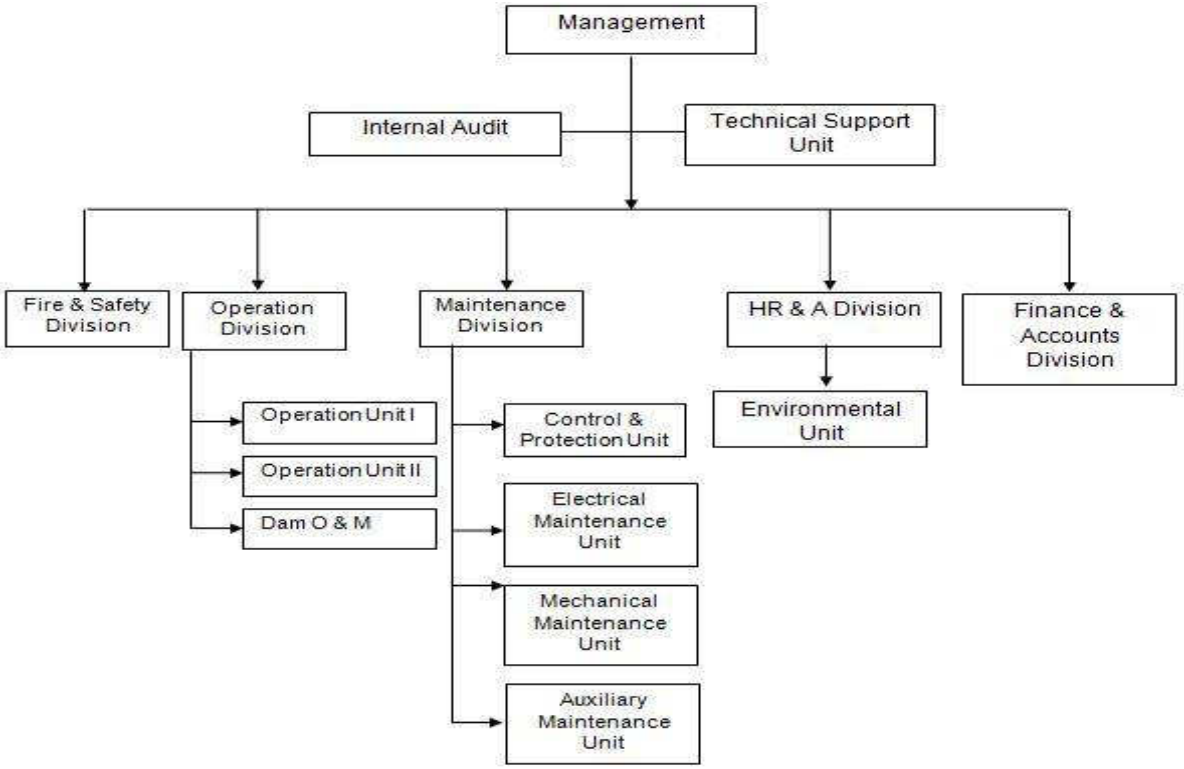


Figure 2-19: Organization structure during the O&M stage.

During the operation and maintenance stage, the General Manager/Plant Head will either report to the regional head or be the regional head, who will report to the Director O&M of DGPC. During the O&M phase, about 322 staffs will be required.The proposed organization structure during the O&M stage is shown in Figure 2-19.

2.11 Operation and Maintenance Activities

Operation and maintenance activities of for hydropower plants are necessary at predetermined time intervals to ensure the following:

1. Quality and reliable operation of equipment in the service environment, through planned periodic inspections and checking of components and systems, together with replacement or rectification of parts wherever required.
2. Maximum availability of equipment and a minimum of unplanned shut downs, by using planned/ periodic shutdowns to inspect all equipment (serviceable and non-serviceable).
3. Eradication of operational problems by timely analysis of the cause of faults/problems and replacement of short-term solutions with long-lasting and permanent ones.
4. Reduce the pollution load (reduced discharges/emissions).

The Pelton Turbine has been proposed for the NHPP. The following section describes activities related to preventive maintenance of the turbine and hydro-generators.

Preventive maintenance of the Pelton turbine: In order to achieve the objectives noted above, time has to be allotted every year for each machine. Normally the periodicity and the procedure for maintenance are recommended by the manufacturer of the equipment. Routine maintenance includes daily, weekly, monthly, and quarterly checks as per the maintenance schedules. These checks are necessary for controlling any change in the installed clearances and commissioning characteristics connected with the performance of equipment.

3 PROJECT ALTERNATIVES

3.1 Introduction

The development of the Nikachhu project has required analysis of various project alternatives, addressing the optimal match between required technical specifications and site conditions, especially geological stability, as well as addressing any concerns for environmental, social, and economic features in each location. Six alternatives were studied. As noted previously, it was concluded that Alternative #3 is the best option. The summary of the various alternatives is noted in Table 3-1.

Table 3-1: Six alternatives for the Nikachhu project.

Description	Alt # 1	Alt # 2	**Alt # 3**	Alt # 4	Alt # 5	Alt # 6
Dam Location[2]	D2	D3	**D2**	D3	D2	D3
Powerhouse Location	PH1	PH1	**PH2**	PH2	PH3	PH3

The acronyms are explained below:
D2 – refers to the dam proposed at Lorim;
D3 – refers to the dam proposed at Banglapokto;
PH1 – refers to the powerhouse proposed at Tangsibji Village;
PH2 – refers to the powerhouse proposed at Norbuodi; and,
PH3 – refers to the powerhouse proposed at Chipchipokto.

The location coordinates for the various dam and powerhouse alternatives are noted in Table 3-2 below.

Table 3-2: Location coordinates for the dam and powerhouse location alternatives.

Location	Coordinates	
	Latitude	Longitude
D2 at Lorim	27°26'55.41"	90°22'22.21"
D3 at Banglapokto	27°26'32.49"	90°24'9.34"
PH1 at Tangsibji	27°26'29.46"	90°27'17.90"
PH2 at Norbuodi	27°29'28.36"	90°29'5.37"
PH3 at Chipchipokto	27°28'39.94"	90°28'50.19"

[2] D1 was discarded, as it was not suitable for the required foundation and intake arrangement.

The details of the alternative options for the dam and powerhouse are discussed in the following section. To a large extent, the dam has to be at a location on the river that makes sense for dam construction, available head, geology, etc. It cannot be moved around due to the nature of the vegetation. Note that all the possible dam locations, being immediately adjacent to the river, will probably have higher vegetation diversity, given the influence of the river on vegetation, the protection provided by extreme slopes, etc. All the detailed EIA surveys were undertaken after the best alternative was determined (based on engineering requirements and some cursory analysis of trees and population proximity). The current dam location was chosen on accord of technical viability in terms of head, geology, and access. In fact, vegetation loss at the current proposed dam site is much less than the other dam site options, due to a shorter road distance (proximity to the National Highway).

3.2 Alternatives

3.2.1 Alternative 1

3.2.1.1 Geotechnical Findings

Alternative 1 is with the dam located at Lorim (D2) and the powerhouse (PH1) at Tangsibji Village. The geological and geotechnical study showed that PH1 lies on fair rock conditions, but with high permeability, consisting almost entirely of garnetiferousmicaceous schist and mica schist, with intrusions of quartz and dykes. From the geotechnical studies, it was concluded that the location of PH1 may be feasible; however, the cost of construction could escalate, due to the presence of high permeability. Drawing from the experiences of the time and cost overrun at the 126 MW Dagachhu Project (in similar kind of geology), this powerhouse option (PH1) was discarded.

Subsequently, two powerhouse locations were identified, with PH2 at Norbuodi and PH3 at Chipchipokto, with rock units comprising granite gneiss with garnetiferous mica schist inter-layers.

3.2.1.2 Power and Energy Potential

In terms of energy potential, Alternative 1 would have an installed capacity of 212 MW, producing on an average a total energy of 812.66 GWh per annum.

3.2.1.3 Construction Cost

The total construction cost was estimated at Nu. 15,962.21 million. It was estimated at the levelized tariff of Nu. 4.29 per kWh of energy.

3.2.1.4 Environmental and Social Implications

As with all other options, the dam would partially touch the Jigme Singye Wangchuck National Park, as the river marks the boundary of the park (this is inevitable and has to be mitigated). The road to the Dam site would be 3.98 km in a degraded forest, while the road to the powerhouse would involve using the existing highway as far as TsheringmaDrupchhu, then connecting to the surge shaft and then to PH1 from the surge shaft. With this option, a total length of 6.78 km of new formation road-cutting was envisaged. However, considering this option, there would still be a need to strengthen roads from Yuesa to TsheringmaDrupchu, for a total travel distance of approximately 30 km. This option would incur a heavy investment. Furthermore, the whole Tangsibji Village would be disturbed in one way or another. With this alternative, about 70 households would be affected.

Conclusion: The Power house location of this alternative is on a highly permeable garnetiferous Mica Schist formation with wetlands on the surface. Such formation shall result in cost escalation during construction. As for the social impacts, it is mainly associated with the construction of 30km access roads which would affect wetland of 70 farming households in two geogs. The dam will include the northern boundary of the JSWNP Park due to submergence at dam site.

3.2.2 Alternative 2

3.2.2.1 Geotechnical Findings

Alternative 2 involves the dam located at Banglapokto (D3) and the powerhouse at Tangsibji Village (PH1). The powerhouse being located on highly permeable strata disqualified this option. The D3 investigation revealed granite bedrock, which represents a strong base for the structure; core boring confirmed to the material strength in order of 20 – 38 MPa, which is very good material. So, D3 is geologically feasible.

3.2.2.2 Power and Energy Potential

In terms of energy potential, this alternative would have an installed capacity of 188 MW, producing an average total energy of 714.20 GWh per annum.

3.2.2.3 Construction Cost and Tariff

The total construction cost was estimated at Nu. 14,024.15 million (with an estimated levelized tariff of Nu. 4.28 per kWh of energy).

3.2.2.4 Environmental and Social Implications

Submergence will affect Park as in Alternative 1.

Conclusion: The Powerhouse location of this alternative is the same as Alternative 1, on a highly permeable geological formation resulting in cost escalation. Also, social impacts are quite significant with 70 households in two geogs being affected from access roads of 30km affecting wetland of farmers.

Dam site (D3) at Banglapokto is also located between the northern boundary of the JSWNP Park and its biological corridor connecting JSWNP to Wangchuck Centennial Park, where construction of a permanent access road to the dam will fall in the easternmost biological corridor.

3.2.3 Alternative 3

3.2.3.1 Geotechnical Findings

Alternative 3 (the preferred option) involves the dam at Lorim (D2) and the powerhouse at Norbuodi (PH2). The strength of the bedrock at the dam is medium-strong to strong, with a bearing capacity of about 50-75 MPa. Therefore, it is the most suitable option (with the optimal geological stability, compared to other options that were examined). Figure 3-1 shows the proposed dam location.

Figure 3-1: Right and left banks of the Nikachhu at D2.

The powerhouse (PH2) geology was reported to have a strength of up to 75MPa. This indicates that it is very suitable for the underground powerhouse.

3.2.3.2 Power and Energy Potential

In terms of energy potential, this option would have an installed capacity of 115 MW, producing an average total energy of 496.56 GWh per annum. As tailrace water is going to be discharged into the Mangdechhu Dam, an additional amount of produced energy (358.06 GWh) is anticipated, which makes the total energy equivalent to 854.62 GWh.

3.2.3.3 Construction Cost and Tariff

The total construction cost is estimated at Nu. 10,770.15 Million. It is estimated at the levelized tariff of Nu. 3.87 per kWh.

3.2.3.4 Environmental and Social Implications

The right side of the dam would abut to the riverbank on the boundary of the JigmeSignyeWangchuck National Park. Submergence due to the reservoir above the diversion weir would occur mostly in the degraded forest on the left bank of the Nikachhu; some would occur on the right bank on the edge of the National Park. The forest in this area is dominated by broadleaf trees and *Quercus* species (oak). Bamboos dominate the ground vegetation. With Alternative #3, the powerhouse (at PH2) would be located underground; the impact on the forest would be due to construction of an access road, similar to all the other options. As the powerhouse and surge shaft will be located in a cattle-degraded forest, environmental concerns are limited to loss of some trees and ground vegetation.

Conclusion: In terms of social implications, this option would have the less effect than the above alternatives, with only 12 households losing some dry land; 9 households for access roads to power house and surge shaft, 2 households for access road to dam site and one institutional land for access road at adit 3. . However, no houses would require relocation.

The dam will impinge the northern boundary of the JSWNP Park due to submergence at dam site. The construction of a temporary access road to Adit 2 will fall in the easternmost biological corridor connecting JSWNP and Wangchuck Centennial Park. Once construction is complete, this access road will be closed and revegetated.

3.2.4 Alternative 4

3.2.4.1 Geotechnical Findings

This alternative involves the location of the dam (D3) at Banglapokto and the powerhouse at Norbuodi (PH2). The characteristics of D3 were discussed under alternative 2 (3.2.2). The characteristics of PH2 were discussed under alternative 3 (3.2.3.).

3.2.4.2 Power and Energy Potential

In terms of energy potential, this option would have an installed capacity of 85 MW. The project itself would generate an average of 352.40 GWh per annum, while there would be additional generation of 358.06 GWh, due to discharge of tailrace water to Mangdechhu Dam. Therefore, the total energy that could be generated per annum would be 710.46 GWh.

3.2.4.3 Construction Cost and Tariff

This alternative would have a construction cost of about Nu. 9,090.26 million (estimated at the levelized tariff of Nu. 4.50 per kWh).

3.2.4.4 Environmental and Social Implications

The topography with this option is very steep, with a slope gradient exceeding over 95%; thus, construction of an access road would be a challenge. Due to the steep topography, excavated materials run down the slopes and cause damage to the vegetation below. Alternative 4, however, has 9 households losing some land, mainly for access roads to power house and surge shaft mostly dry land.

Conclusion: In terms of social implications, this option will affect nine households. The Dam site (D3) at Banglapokto is also located at the northern boundary of the JSWNP Park. The construction of a permanent access road to the dam will fall in the easternmost biological corridor connecting JSWNP to Wangchuck Centennial Park. .

3.2.5 Alternative 5

3.2.5.1 Geotechnical Findings

This alternative combines D2 with PH3. Geologically, both the sites are stable.

3.2.5.2 Power and Energy Potential

In terms of energy potential, this option would have an installed capacity of 115 MW, producing an average total energy of 496.26 GWh per annum. As tailrace water would be discharged into the Mangdechhu Dam, additional energy of 358.06 GWh would be produced, making the total energy production 854.32 GWh.

3.2.5.3 3.2.5.3 Construction Cost and Tariff

This alternative would have a construction cost of about Nu. 10,683.53 million (estimated at the levelized tariff of Nu. 3.84 per kWh).

3.2.5.4 Environmental and Social Implications

Social impacts include impacts on two households at the dam site and an institutional land at Banglapokto. Social impacts are lower due to the inaccessible topography. Environmental considerations are similar to Alternative 3.

Conclusion: Since the dam location is the same as Alternative 3 the environmental issues will be similar. However, in this alternative, the access to the Power House will have problems of inaccessibility as it is located on Chipchipokto which is very steep (>95%).

3.2.6 Alternative 6

3.2.6.1 Geotechnical Findings

The combination with Alternative 6 is with the dam (D3) at Banglapokto and the powerhouse (PH3) at Chipchipokto. Geologically, both the dam and powerhouse sites are suitable.

3.2.6.2 Power and Energy Potential

In terms of energy potential this option would have an installed capacity of 85 MW. The project itself would generate an average of 352.03 GWh per annum, while there would be additional generation of 358.06 GWh, due to discharge of tailrace water to the Mangdechhu Dam. The total energy that could be generated per annum would be 710.09 GWh.

3.2.6.3 Construction Cost and Tariff

This alternative would have a construction cost of about Nu. 9,090.26 million (estimated at the levelized tariff of Nu. 4.50 per kWh).

3.2.6.4 Environmental and Social Implications

D3 environmental and social implications were discussed in Alternative 2 (3.2.2) and PH3 implications were discussed in Alternative 5 (3.2.5).

Conclusion: In terms of social implications, this option would have the least effect. In terms of environmental impacts, since the dam site here is D3, at Banglapokto so environmental impacts are more significant as it falls in the Biological corridor as well as the JSWNP. However, in this alternative, the access to the Power House will have problems of inaccessibility as it is located on Chipchipokto which is very steep (>95%).

3.2.7 Consideration of all Alternatives

With respect to environmental considerations, under Alternatives 2, 4, and 6, the Dam site (D3) at Banglapokto is also located between the northern boundary of the JSWNP Park and the biological corridor. The construction of a permanent access road to the dam will fall in the easternmost biological corridor connecting JSWNP to Wangchuck Centennial Park. For alternative 6, the steep topography and inaccessibility of the road to Power house provides additional environmental challenges.

Thus based on environmental considerations, alternatives 1, 3 & 5 were selected. However, Alternative 1 was rejected as the number of affected households is the highest with this alternative. The location of the Power house below Tangsibji village will affect 70 households that will lose some of their wetland for the construction of permanent access road.

This leaves Alternative 3 and 5. While Alternative 3 and 5 would only affect 12 households and 3 households respectively and the geology and levelised tariff requirement for both the alternatives are comparable.

Alternative 5 was however rejected due to accessibility issues at Power House as it is located on Chipchipokto which is very steep (>95%).

3.3 Alternative Summary

Table 3.3 provides an overview of all six alternatives in terms of installed capacity, energy generation, levelized tariff and technical details.

Table 3-3: Summary of alternatives

Features	Unit	Alt#1	Alt#2	Alt#3	Alt#4	Alt#5	Alt#6	No project
Installed Capacity	MW	212.00	188.00	115.00	85.00	115.00	85.00	0
Energy (90% dependable year)	GWh	812.66	714.20	496.56	352.40	496.26	352.03	0
Additional energy from Mangdechhu	GWh	0	0	358.06	358.06	358.06	358.06	0
Total energy	GWh	812.66	714.20	854.62	710.46	854.32	710.09	0
Catchment area	km^2	373.00	398.00	373.00	398.00	373.00	398.00	0
GLOF	NO GLOF							0
Average flow	m^3/s	18.36	19.59	18.36	19.59	18.36	19.59	0
Max flow	m^3/s	109.58	116.92	109.58	116.92	109.58	116.92	0
Min flow	m^3/s	2.94	3.13	2.94	3.13	2.94	3.13	0
Reservoir Length	m	464.41	289.00	464.41	289.00	464.41	289.00	0
Reservoir area	km^2	0.0213	0.0130	0.0213	0.0130	0.0213	0.0130	0
Diversion tunnel length	m	300.00	448.00	300.00	448.00	300.00	300.00	0
Shape of diversion tunnel	Horse Shoe							0
Diameter of diversion tunnel	m	4.56	4.71	4.56	4.71	4.56	4.71	0
Dam height above river bed	m	19.55	19.61	19.55	19.61	19.55	19.61	0
Dam crest length	m	46.50	46.80	46.50	46.80	46.50	46.80	0

Features	Unit	Alt#1	Alt#2	Alt#3	Alt#4	Alt#5	Alt#6	No project
De-silting chamber length	m	255.30	277.10	256.25	275.75	256.25	275.75	0
HRT length	m	7,285	4,892	13,250	10,310	12,300	9,100	0
Diameter of HRT	m	3.30	3.40	3.30	3.40	3.30	3.40	0
Surge shaft height	m	43.75	39.47	59.24	56.11	56.93	52.60	0
Diameter of Surge Shaft	m	10.5	10.5	10.5	10.5	10.5	10.5	0
Pressure shaft (steel lined)	m	780	707.00	535.00	375.00	528.00	369.00	0
Main access tunnel length	m	1,204.00	1,204.00	590	590	651.50	651.50	0
Size of underground Power House	m	93x18x40	93x17x40	60.85x17x37.4	60.85x17x37.4	60.85x17x37.4	60.85x17x37.4	0
Cost of construction (million)	Nu.	15,962.21	14,024.15	10,770.15	9,090.26	10,683.53	9,090.26	0
Levelized tariff (Nu./KWh)	Nu.	4.29	4.28	3.87	4.50	3.84	4.50	0
Geological considerations		Dam2-good PH1-high permeability	Dam3-good PH1-high permeability	Dam2-good PH2-good	Dam3-good PH2-good	Dam2-good PH3-good	Dam3-good PH3-good	0

Features	Unit	Alt#1	Alt#2	Alt#3	Alt#4	Alt#5	Alt#6	No project
Environmental considerations		0.0014% * Temporary access road to Adit 2 through BC**	0.0014% * Permanent access road to Dam3 through BC**	0.0014% * Temporary access road to Adit 2 through BC**	0.0014% * Permanent access road to Dam3 through BC**	0.0014% * Temporary access road to Adit 2 through BC** Topography to PH –very steep and inaccessible	0.0014% * Permanent access road to Dam3 through BC** Topography to PH –very steep and inaccessible	Refer Table 3-4
Social Considerations		70 HH***	70 HH***	12 HH***	9 HH***	5 HH***	2 HH***	Refer Table 3-4

**Submergence due to dam on 0.0014% of the JSWNP, which falls in buffer zone*

***This is unavoidable for all alternatives because possible location of the dam sites (selected based on technical and economic assessments)*

**** Affected households excluding 6HH for Transmission lines which will be the same for all alternatives*

3.4 The "Do Nothing" Alternative

The project has been compared to the scenario of not having a project (which means maintaining the status quo). Table 3-4 below provides a summary of findings, and makes the case for the conclusion that maintaining the status quo is not a vible option. With the project, there are only 12 households that would be affected; they are willing to compromise their land holdings for compensation (based on the consultation of July 25, 2012). There is, therefore, hardly any issue with regard to social aspects (see Part 3). With regard to potential environmental issues. It is expected that these can all be mitigated such that impacts are acceptable (the case is made for this in Section 6 of this Part and Part 2: the EMP).

Table 3-4: Comparison of scenarios.

"Do Nothing" Alternative	Having a Project (Alternative 3)
Social	
Existing scenario will remain as it is as development will be based on 11th Five Year	Negative impact: 12 HH will be impacted by the project but these will be mitigated through the RP.

"Do Nothing" Alternative	Having a Project (Alternative 3)
Plan of dzongkhag.	Additional benefits: Total budget allocated for Community development - Nu.18.04million • Community Development Programs- - Construction of hostel for community school - Provision of agriculture and dairy produce sales outlet • Local employment opportunities (construction work, afforestation, nursery development, land management). • Increase in business opportunities through - Rental of houses - Hire of vehicles - Sale of local produce • Skills Development Training Program for displaced household members and community • Development and preparation of waste disposal site for Tsangkha, Tangsibji and Trasiling and provision of Garbage Compactor Truck for dzongkhag • Black topping of 2.5km farmroad at Tangsibjji • Due to the project and increase accessibility the local land value could increase.
Environmental	
Existing environment will remain as it is with no impacts	Major negative impacts include: • Submergence of 0.0014% of the JSWNPark, which falls in the buffer zone. • Construction of a temporary access road will fall in the biological corridor. This will be reforested after 1.5 to 2 years. • Loss of forest cover for project activities totals 312 acres. • Other environmental impacts are detailed in Chapter 6. Additional benefits: Positive impacts include • Extension of the grid to meet construction requirements will enable additional households

"Do Nothing" Alternative	Having a Project (Alternative 3)
	to be electrified so switching over to electricity for cooking and lighting will result in reduction of demand for fuelwood and promote better health and hygiene. • Formation of a Biodiversity Conservation Committee will ensure that Conservation is given high priority in minimizing negative impacts and identifying and prioritizing conservation efforts. • compensatory afforestation measure will ensure that twice the size of the forest cleared (624.34 acres) will be either afforested or revegetated with local species, undertaken by Department of Forest through a signed MoU. • Initiation of Wildlife Conservation Programs and Plant rescue programs as well as provision of support to the Park through technical support such as Aquatic specialist and Wildlife specialist, budget for biodiversity surveys, patrolling/surveillance. • land management of already degraded forests and promotion of Catchment Management programs. • other environmental impacts will be mitigated through the EMP.
Carbon Savings	
• Opportunity lost.	• 491.52 GWh will offset 459,734 tons of CO_2e per year (carbon dioxide equivalent) through export of energy[3].
Foreign Currency Earnings	
• Earning opportunity lost.	• 491.52 GWh will earn about 2 Billion Indian Rupees per year on average over 25 years.

With the project, the existing education and health facilities may be upgraded during construction and operation of the project. To counter the loss of land and livelihood, the project will provide an opportunity to the local population to get employment, as there is a need to recruit about 2,000

[3] Appling Emission Factor of 0.9467 tCO_2/MWh as per Baseline Database for Indian Power Sector (version 8) published by CEA, India.

personnel for the project during construction stage and 231 personnel during operation stage. The project will offer employment opportunities to local skilled, semi-skilled and non-skilled personnel. The project will also fetch additional foreign exchange revenues after the sale of power to India. Industries which are expected to come up in the adjoining area, due to availability of electricity, will provide additional employment opportunities to the local population. The project is also going to help replace domestic fuel wood with electricity, thereby reducing health impacts on domestic households, and reducing the loss of forest cover. The project is also expected to generate 'carbon savings" due to replacement of fossil fuel-based thermal power with hydropower. Finally, development of new roads and feeder roads, due to the project, will provide easy access to remote habitations and will reduce travel time from east to west.

3.5 Alternatives for Project Ancillaries

Construction Adits – Based on the finalized site for the dam, HRT and powerhouse, the construction adits to expedite construction of the HRT, which is on a critical path of the project, are being located considering geological and techno-economic factors. While locating portals for adits, consideration was also made to have minimal socio-environmental impacts to the extent possible. Generally, alternative location and alignment of adits is limited as it is mainly governed by alignment of the HRT, which is already fixed based on the location of the dam and powerhouse and also on geo-technical considerations. Other project components like the surge shaft, pressure shaft are located based on the finalized site for the powerhouse and other techno-economic considerations.

Access roads – The total road length required to be constructed in the project area to access various work sites is about 18 km. While planning the road alignment, consideration has been given to have the least impact on socio-environmental features of the area. The road has been planned after carrying out a detailed survey at the scale of 1:1,000 and 1 m contour interval in the DPR stage. This level of survey and planning is generally carried out during the pre-construction stage of the project. Availability of such detailed contour map has enabled proper planning and alignment of the road.

Contractor's facilities like batching plant, workshop, labor camp, site office, transit camps, etc. have been tentatively planned and located after detailed assessment of the site with respect to major work sites such as the dam, adits, surge shaft and powerhouse. While locating the above-noted facilities, consideration has been given to have minimal impacts to the surrounding environment. In keeping in line with government directives, the management has put in immense effort to avoid private lands to locate the above facilities. Since the project construction will be carried out through EPC/Turnkey Contractors, the above facilities required by them for construction

of the project are generally planned and managed during the pre-construction stage, based on construction methodology and equipment planning.

The Master plan for the project colony and office space is generally prepared during the pre-construction phase of the project. The most appropriate location has been studied keeping in view the location of major project components and future O&M needs. Effort has been made to avoid private land to the extent possible.

3.6 Carbon Sequestration

Carbon sequestration (due to the project and trees planted as compensatory afforestation), has been calculated and expressed in tCO2e (see Table 3-5). The following calculation factors and assumptions were applied:

- Baseline emission factor of 0.9467 tCO2 / MWh (as per Central Electricity Authority CO2 database version 8 and power generation data of power plants in Bhutan).
- As per the US EPA, a coniferous tree (Bhutan falls in coniferous belt), growing in an urban environment, sequesters 23.2 lbs[4] of carbon during a 10 year growth period. While most trees take one year in a nursery to reach the seedling stage, trees grown under different conditions and trees of certain species may take longer (up to 6 years). Average survival rates of trees in urban areas are based on broad assumptions, and the rates will vary significantly depending upon site conditions. Carbon sequestration is dependent on growth rate, which varies by location and other conditions.
- Loss of carbon sequestration potential, due to the cutting of trees required for work sites, has not been included, as twice the area to be cleared will be re-planted, which over time will cancel (or even over-compensate) for the loss of carbon sequestration potential.
- Energy consumption due to construction equipment has not been factored in, as it will be a transient GHG emission, compared to the long-term carbon sequestration potential created by the project.

[4] http://www.epa.gov/cleanenergy/energy-resources/refs.html

Table 3-3: Carbon offset by the Nikachhu HPP

Explanation	Quantity
GHG emission reduction potential within the project boundary. *The net electricity is calculated after deducting 1.2% as auxiliary consumption. This will also form the basis of emission reduction in the CDM PDD in line with UNFCCC approved methodology ACM0002*	Annual Net electricity export – 485,617 MWh Baseline emission factor – 0.9467 tCO_2/MWh Thus, emission reductions = 485,617 x 0.9467 = 459,734 t CO_2
No. of trees to be planted under Compensatory Afforestation	307,376
Carbon sequestration by a single growing tree for 10 years	= (23.2 lbs x 44/12[5]) / 2.2046 = 39 kg CO_2 = 0.039 tCO_2 / 10 years
Thus, carbon sequestration due to Compensatory Afforestation	307,376 x 0.039 tCO2 /10 years = 1198.8 tCO_2 per year
Total avoidance of GHG (due to electricity generation) and carbon sequestration from the project (tree plantation)	459,734 tCO2 (permanent) + 1,198.8 tCO2 (for the initial 10 years of tree and then the rate will change) = 460,933 tCo2 (approximately)

[5] Carbon to Carbon dioxide conversion factor

4 REGULATORY FRAMEWORK

4.1 Introduction

A comprehensive review of the relevant parts of the constitution, policies, acts, and regulations of Bhutan was carried out, as required for the ESIA process for the Nikachhu project. This included a description of guidelines and standards, which will assist the project proponent/operator in compliance with the various acts and rules. In this section, the procedure for obtaining environmental clearances is also described, along with a checklist of compliances required for the NHPP and also to meet Bhutan's international commitments. Note that many of required environmental clearances have already been obtained.

4.2 Policies and Acts

In this section, the constitution of the Kingdom of Bhutan is described, followed by the strategy and umbrella act pertaining to the environment and forests, biodiversity, and environmental assessment. This is then followed by other acts that regulate different aspects of hydropower development. These include acts on land, mines and minerals, road, electricity, waste, and local governance. The various applicable rules under these acts are also described.

4.2.1 The Constitution of the Kingdom of Bhutan

The constitution of the Kingdom of Bhutan was promulgated on 18th July, 2008. The constitution declares itself as a "Supreme Law" of the State. It declares: the Supreme Court shall be the guardian of this Constitution and the final authority on its interpretation; the rights over mineral resources, rivers, lakes and forests shall vest in the State and are the properties of the State, which shall be regulated by law. Specific provisions under Article 4, Article 5 and Article 7 of the constitution are applicable to the NHPP. These provisions are described below.

Article 4 on Culture: The State shall endeavor to preserve, protect and promote the cultural heritage of the country, including monuments, places and objects of artistic or historic interest, Dzongs, Lhakhangs, Goendeys, Ten-sum, Nyes, language, literature, music, visual arts and religion to enrich society and the cultural life of the citizens.

Article 5 on Environment: 1. Every Bhutanese is a trustee of the Kingdom's natural resources and environment for the benefit of the present and future generations and it is the fundamental duty of every citizen to contribute to the protection of the natural environment, conservation of the rich biodiversity of Bhutan and prevention of all forms of ecological degradation, including noise, visual and physical pollution, through the adoption and support of environment friendly practices and policies; 2. The Royal Government shall: (a) protect, conserve and improve the pristine

environment; and safeguard the biodiversity of the country; (b) prevent pollution and ecological degradation; (c) secure ecologically balanced sustainable development while promoting justifiable economic and social development; and, (d) ensure a safe and healthy environment; 3. The Government shall ensure that, in order to conserve the country's natural resources and to prevent degradation of the ecosystem, a minimum of sixty percent of Bhutan's total land shall be maintained under forest cover for all time; 4. Parliament may enact environmental legislation to ensure sustainable use of natural resources and maintain inter-generational equity and reaffirm the sovereign rights of the State over its own biological resources; 5. Parliament may, by law, declare any part of the country to be a National Park, Wildlife Reserve, Nature Reserve, Protected Forest, Biosphere Reserve, Critical Watershed, and such other categories meriting protection.

Article 7 on Fundamental Rights: A Bhutanese citizen shall have the right to freedom of movement and residence within Bhutan. A person shall not be deprived of property by acquisition or requisition, except for public purpose and on payment of fair compensation in accordance with the provisions of the law.

4.2.2 The Environmental Strategy 1998

The National Environment Strategy for Bhutan defines hydropower development as a sustainable and relatively clean source of revenue, which Bhutan needs in order to finance other aspects of both its development and conservation agendas.

4.2.3 Water Act of Bhutan 2011

The Act came into force on May 4, 2011. The purpose of the Act is to: 1) ensure that the water resources are protected, conserved and/or managed in an economically, efficiently, socially equitable, and environmentally sustainable manner; and, 2) establish suitable institutions.

The salient features of the Act relevant to hydropower development are:

1) Water resources are the property of the State. The rights over water resources, including the bed and banks of watercourses, shall vest in the State.

2) The Royal Government, as the public trustee of the nation's water resources, shall ensure that water is protected, conserved and/or managed in accordance with the principles set out in this Act.

3) Every individual shall have access to safe, affordable and sufficient water for basic human needs.

4) A National Integrated Water Resources Management Plan shall be formulated for coordinated development, management, conservation and efficient use of water resources.

5) Polluter pays principle.

6) User pays principle.

7) The National Environment Commission Secretariat is the custodian of the Act.

8) The powers and functions of competent authorities been delineated in the implementation of the Act.

9) There are minimum environmental flow requirements for watercourses.

10) A person intending to abstract water shall seek an approval from the Commission prior to conducting feasibility studies. The approval shall contain terms and conditions, including upstream and downstream water use issues.

11) Domestic use, small scale drinking water supply and irrigation use, running small water mills, water grinders or prayer wheels shall not need environmental clearance, but should follow best water management practices.

12) The water use priorities are:
- water for drinking and sanitation;
- water for agriculture;
- water for energy;
- water for industry;
- water for tourism and recreation; and
- water for other uses.

13) Effluents shall be treated using best available technology before discharging into the environment.

4.2.4 National Environment Protection Act 2007

This act came into force on July 31, 2007. It is an act to provide the establishment of an effective system to conserve and protect environment through the National Environment Commission Secretariat or its successors, designation of competent authorities, and constitution of other advisory committees, so as to independently regulate and promote sustainable development in an equitable manner. It is guided by environmental principles, which states that the people and the government in succession shall perpetually strive to consider and adopt its developmental policies, plans and programs in harmony with the environmental principles.

These include the **fundamental right** to a safe and healthy environment with equal and corresponding duty to protect and promote the environmental wellbeing of the country; **inter-generational equity** to ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations; **middle path strategy** for development**; precautionary principle –** where there are threats of serious or irreversible damage,

lack of full scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation. Therefore, a developmental activity shall be strategically planned and executed in harmony with the carrying capacity of the country's sensitive ecological settings and geographical terrains; **principle of 3Rs** to be used for forestalling or limiting environmental impact from the start; **polluter pays principle** for the costs of containment, avoidance, abatement, medical compensation, mitigation, remediation and restoration. The uniformity of the system of environmental protection shall be guaranteed by the government, the local governments and the private sector through appropriate policies, plans and programs such as environmental assessment processes, regulations, incentives, fiscal policies and other instruments; **right to information,** where every individual has the right to be informed about the state of the environment and all activities which are being proposed that could affect the environment; **access to justice –** any individual whose right to a safe and healthy environment has been affected or is likely to be affected shall have the right to seek legal redress.

Sovereign rights principle – the state has sovereign rights over renewable and non-renewable natural resources within the limits of its national jurisdiction. Conservation of natural resources shall be based on a participatory approach aimed at achieving an equitable sharing of the costs and benefits of conservation among resource users; **principle of payment for environmental services –** a person using or extracting natural resources shall be liable to pay for ecosystem/environmental services. The act empowers "the National Environment Commission Secretariat" as an independent authority and the highest decision making body on all matters relating to the environment and its management in the country. The commission shall exercise the jurisdiction and powers and discharge the functions and duties conferred or imposed by or under this act. Chapter IV describes protection of environmental quality; Chapter V describes protection of forest, biodiversity and integrity; Chapter VI describes environmental financing and incentives; Chapter VII describes the right to environmental information and citizens' participation; Chapter VIII describes the procedure for inspections and verification; and, Chapter IX describes enforcement, offences, and penalties.

4.2.5 Forest and Nature Conservation Act 1995

The first environmental legislation to be passed in Bhutan was the Bhutan Forest Act 1969, which brought all forest resources under government custody with the intent to regulate forest utilization and control excessive forest exploitation. This law was repealed in 1995, with the enactment of the Forest and Nature Conservation Act (FNCA) 1995, in keeping with evolving conservation needs and to allow for community stewardship of forests. The objective of the FNCA is to "provide for the protection and sustainable use of forests, wildlife and related natural resources of Bhutan for the benefit of present and future generations". The act covers forest management, prohibitions and concessions in government reserved forests, forestry leases, social and community forestry,

transport and trade of forestry produce, protected areas, wildlife conservation, soil and water conservation, forest fire prevention, and enforcement and penalties.

Protected areas are regulated under this act in Bhutan. A protected area is an area which has been declared to be a national park, conservation area, wildlife sanctuary, wildlife reserve, nature reserve, strict nature reserve, reserve forest, or critical watershed. Other protected areas include areas for the preservation of natural beauty of national importance, protection of biological diversity, management of wildlife, conservation of soil and water and related purposes. A Protected Area includes various management zones classified as: core zone, buffer zone, administrative zone, seasonal grazing zone, enclave zone, and multiple use zone. Schedule I of the Act provides a list of wild animals and plant species that needs full protection in Bhutan.

In accordance with the powers and duties conferred under the FNCA, the Ministry of Agriculture has promulgated the Forest and Nature Conservation Rules (FNCR) 2000, to allow for:

- preparation, review, approval, implementation, monitoring and evaluation of forest management plans;
- reservation of government reserved forests, allotment of land and land rights in government reserved forests, regulation of activities in lands allotted for private use, collection of forest produce from government reserved forests, compensation for acquired lands, prohibitions, restrictions and concessions in government reserved forests, and forestry leases;
- creation of private and community forests, including procedures for registration of private and community forests and effects consequent upon registration, management and use of community forest resources, and responsibilities and powers of the community forest management group and concerned government agencies;
- transport and trade of forest produce, including extraction and marketing procedures and inspection of forest produce in transit or in trade;
- declaration of protected areas (PA), administration of PAs, and prohibitions in PAs;
- protection of wildlife and use of certain wild species;
- prevention of forest fires, land clearance, and activities potentially impacting soil, water and wildlife resources; and,
- Enforcement and penalties for offences related to all of the above.

4.2.6 Biodiversity Act 2003

The purposes and objectives of this Act include:

- To ensure national sovereignty of the RGOB over genetic resources in accordance with relevant national and international law;
- To ensure the conservation and sustainable use of the biochemical and genetic resources;
- To promote the equitable sharing of benefits derived from the use of genetic resources;
- To promote technology transfer and capacity building at the national and local levels, including the building of scientific and technological capacity relevant to the conservation and sustainable use of biological diversity;
- To recognize and protect traditional knowledge, innovation and practices of local communities associated with biodiversity;
- To regulate and facilitate the process by which collectors may legally obtain genetic resources;
- To prevent illegal access to genetic and biochemical resources and associated traditional knowledge;
- To recognize and protect the farmers' and breeder's rights;
- To make plant varieties subject to property rights;
- To ensure that plant breeders are able to recover the cost from useful improvements and innovations, and continue to do so;
- To provide legal recognition of varieties which are not protectable under the internationally existing patent and/or plant breeders rights laws and thereby recognize farmers' plant variety improvements and innovations and provide a means of sharing benefits derived from the use of farmers' or traditional varieties as breeding material for commercial purposes and to promote access to foreign sources of improved plant varieties to Bhutanese farmers;
- This Act shall apply to all the genetic and biochemical resources including wild, domesticated and cultivated species of flora and fauna, both *in-situ* and *ex-situ* conditions found within the territory of the Kingdom of Bhutan;
- The procedure and conditions provided by this act shall apply even if the genetic resources for which access is sought are located in protected areas or government reserved forests; and,
- The provision of this Act shall apply to the traditional knowledge, innovation and practices associated with biodiversity.

Chapter 2 of this act describes access to genetic resources and benefit sharing conditions of access. Chapter 3 describes a *sui generis* system for the protection of plant varieties. Chapter 4 describes provisions for protection of traditional knowledge. Chapter 5 describes provisions of offences and penalties. Chapter 6 provides a description of rules and regulations, amendments, interpretation, and definitions.

4.2.7 EA Act 2000

This Act establishes procedures for the assessment of potential effects of strategic plans, policies, programs, and projects on the environment, and for the determination of policies and measures to reduce potential adverse effects and to promote environmental benefits. It makes environmental clearance (EC) mandatory for any project/activity that may have adverse impact(s) on the environment.

Based on the review of environmental information submitted by the project applicant, the National Environment Commission Secretariat (NECS) or the Competent Authority (CA) may issue/deny EC or determine the need for a full environmental assessment (EA). Where a full EA is determined necessary, the applicant will be asked to prepare EA documents according to the terms of reference (ToR) approved by the NECS. The NECS will review the EA report and accordingly issue/deny EC.

The NECS or CA may issue EC based on the following: (a) the effects of the project on the environment are foreseeable and acceptable; (b) the applicant is capable of carrying out the terms of EC; (c) the project, alone or in connection with other programs/ activities, contributes to the sustainable development of the Kingdom and the conservation of its natural and cultural heritage;(d) adequate attention has been paid to the interests of the concerned people; and, (e) the project is consistent with the environmental commitments of the Kingdom.

As per Article 16 of the act, public consultation is mandatory. EC for a project shall be reviewed and may be revised and renewed at least every five years, unless a shorter period is stated. The NECS or CA may review and modify the terms whenever there are: (a) unacceptable risks to the environment resulting from the project which were not known at the time the clearance was issued; (b) availability of improved and cleaner technology; and, (c) a need to bring the project into compliance with changes to the laws of the country.

Non-compliance with environmental terms specified in the issuance of environmental clearance makes the offender liable to penalties that may include compensation for environmental damage, fines, sanctions, and suspension or revocation of environmental clearance in part or full.

4.2.8 Land Act 2007

The latest amended Land Act is the 2007 version. Under this act, the acquisition of any land, constructions or other property occurs in accordance with the procedures established. Land use of the project area assists in identifying land ownership. Land use is classified under Chuzhing, Kamzhing, Tseri, Tsamdo, and Sokshing. Forest land can be classified under broad leaf, coniferous, scrub land, and wetland. The ownership can be either: (a) “private”; or, (b) “public”. For

private land, the number of affected families needs to be identified. These data will be used to work out resettlement requirements and compensation payable. **"Affected Families"** are those who own or occupy the area and are dependent on it for their livelihood. They may or may not be the actual landowner. The key points of the Act applicable for hydropower projects are:

- As far as possible, the government shall provide land substitution instead of cash compensation while acquiring land.
- Allotment of all substitute land shall be within the same Dzongkhag.

In case the project acquires a house, the compensation for any category of house, whether built with RCC/brick/stonemasonry or in traditional style, shall be paid on the basis of evaluation carried out in each case by a qualified engineer appointed by a competent authority. The Land Compensation Rate 2009 governs the compensation.

4.2.9 Mines and Minerals Management Act 1995

The Mines and Minerals Management Act 1995 provides a framework for exploring mineral resources in the country. This also complements the EA Act 2000, as it has provisions for environmental requirements. The relevance of this Act for a hydropower project is when the project requires quarries for sand or stone, this law is enforced to get the site clearance.

4.2.10 Road Act 2012

The Road Act 2004 was amended in the 2012 session of the parliament. The key changes in the 2012 amendment were mainly related to farm roads and state that those households holding 2 acres or less and losing land to a project exceeding 10 DC (01 DC = 40.47 m^2) will be eligible for compensation. The Act establishes a framework to ensure balanced socio-economic development, promote social equity, and define and establish an efficient system of road networks. According to the Act, the construction of access roads for a hydropower project falls directly under the jurisdiction of Ministry of Trade and Industry (present Ministry of Economic Affairs), which is termed as a power road.

4.2.11 Bhutan Electricity Act 2003

This act provides a framework for licensing and regulating the operations of power companies. Under this act, the Bhutan Electricity Authority has been established as an autonomous body and the custodian for enforcing this act. The Electricity Act provides power to acquire land and water for generation and supply of electricity.

4.2.12 Waste Prevention and Management Act 2009

This Act shall extend to all forms of waste, whether solid, liquid, or gaseous, hazardous or non-

hazardous, organic or inorganic, from residential, agricultural, commercial, medical or industrial sources, produced by any person, including materials being stored for recycling or in the process of recycling, including the transportation of waste in any form, and import and export of waste in Bhutan. The purpose of the Act is to protect and sustain human health through protection of the environment by:

(a) reducing the generation of waste at source;

(b) promoting the segregation, reuse, and recycling of wastes;

(c) disposal of waste in an environmentally sound manner; and,

(d) effective functioning and coordination among implementing agencies.

It states that: all developmental activities that generate waste shall be planned and executed in harmony with the carrying capacity of the country's fragile ecological settings and geographical terrains; a person polluting the environment or causing ecological harm shall be responsible for the costs of avoidance, containment, abatement, medical compensation, mitigation, remediation and restoration; all persons shall operate in line with the concept of 3 Rs, which are as follows:

(a) Avoid, eliminate, or substitute the use of products or unnecessary packaging that generates waste.

(b) Reduce the generation of waste from the manufacture and use of products.

(c) Reuse products and packaging materials.

(d) Recycle material from waste for production of new and useful products.

(e) Recover material from waste for energy production and other uses.

(f) Treat and dispose waste to reduce and eliminate harm to the environment.

(g) Treat and dispose waste to avoid harm to human health.

Implementing agencies shall ensure that the reduction, reuse, recycling and disposal of non-hazardous waste are addressed in an environmentally sound manner. Implementing agencies shall prevent manufacturing of products with the potential to generate hazardous waste. The agencies shall also ensure that the reduction, storage, treatment, and disposal of hazardous waste are addressed in an environmentally sound manner. Implementing agencies shall ensure that the minimization, storage, treatment and disposal of medical, pharmaceutical and other biologically hazardous waste are addressed in an environmentally sound manner. In doing so, agencies shall ensure appropriate pre-treatment of this type of waste. Implementing agencies shall ensure that the minimization, storage, treatment and disposal of waste from the production and use of electrical and electronic equipment are addressed in an environmentally sound and safe manner. In doing so, a system shall be established by the relevant implementing authority to provide for the proper collection, treatment and safe disposal of end-of life electrical and electronic equipment.

4.2.13 The Local Government Act of Bhutan, 2009

Upon enactment of this Act, the Local Government Act 2007; Thromde Act 2007; Dzongkhag Yargay Tshogdu Chathrim, 2002; Geog Yargay Tshogchung Chathrim, 2002; and the provisions of any law, by-law, regulations, circular, and order that is inconsistent with this Act, were repealed.

Local Governments shall comprise the following categories:

(a) The Dzongkhag Tshogdu, supported by the Dzongkhag Administration in each Dzongkhag;

(b) The Geog Tshogde, supported by the Geog Administration in each Geog; and,

(c) The Dzongkhag Thromde Tshogde, supported by the Dzongkhag Thromde Administration in each Dzongkhag Thromde.

The Dzongkhag Tshogdu shall be the highest decision making body in the Dzongkhag. It shall comprise the Gup and Mangmi as the two elected representatives from each Geog, one elected representative to represent the Dzongkhag Thromde and one elected representative to represent the Yenla Throm. The Dzongkhag Tshogdu shall not be a law-making body, and thus shall not have legislative functions, while it may make rules and regulations consistent with national laws. Dzongkhag capital towns in the immediate vicinity of the Dzongkhag Administration Secretariat which do not have adequate economic and administrative capacity to function independently shall be considered as Dzongkhag Thromde. The Dzongkhag Thromde Tshogde shall decide all issues pertaining to the planning and budgeting of these towns which shall be managed by a town committee under control of the Dzongkhag Administration. The Dzongkhag Thromde Tshogde shall not be a law making body, and thus shall not have legislative functions while it may make rules and regulations consistent with national laws. The Geog Tshogde shall be the highest decision making body in the Geog. It shall comprise the Gup, Mangmi and Tshogpas. It shall not be a law making body, and thus shall not have legislative functions while it may make rules and regulations consistent with national laws. Functions of Local Governments as per this act are given below:

- Provide democratic and accountable government for local communities;
- Ensure the provision of such social and economic services for the general wellbeing of the residents of the communities in a sustainable and equitable manner;
- Ensure that development occurs in a planned and harmonious manner;
- Undertake any activity consistent with other relevant laws and policies of the country which may conserve and enhance the environment within the limits of the areas under its jurisdiction;
- Encourage the involvement of communities and community organizations in matters of local governance; and,

- Discharge any other responsibilities as may be prescribed by Parliament.

Local Governments shall be supported by the Central Government in the development of administrative, technical, and managerial capacities and structures which are responsive, transparent and accountable. Local Governments shall be entitled to levy, collect and appropriate taxes, duties, tolls and fees in accordance with such procedure and subject to limitations as may be provided for by law. Local Governments shall be entitled to financial resources from the Government in the form of annual grants. Local Governments shall be allocated a proportion of the national revenue to promote self-reliant and self-sustaining units or activities of Local Self-Government. Local Governments shall be supported by the Government to promote holistic and integrated area-based development planning. Local Governments shall be entitled to own assets and incur liabilities by borrowing on their own account, subject to such limitations as may be provided for by law.

4.2.14 Bhutan 2020: A Vision for Peace, Prosperity and Happiness

The 2020 Vision Document envisages adding 1,000 MW of hydropower generation capacity by the year 2012, and another 2,000 MW by the year 2017. Bhutan has therefore embarked upon the following approaches, methodologies, strategies and initiatives to achieve the national goals:

a) Preparation of 20 Years' Power System Master Plan (PSMP) for sustainable hydropower development and Water Resources Management Plan on the basis of technical, economic, social and the environmental considerations.

b) Preparation of the Rural Electrification Master Plan for achieving 100% electricity access by 2020 and to fulfill the Millennium development goals of the energy sector.

c) Preparation of the Integrated Energy Management Plan for sustainable supply and demand management of energy resources for economic development.

d) Development of legal and policy frameworks for re-structuring and reforming the power sector.

4.2.15 Bhutan Sustainable Hydropower Development Policy 2008

The key objectives of the policy are to:

a) Mobilize funds and attract investments for accelerated hydropower development.

b) Enhance the revenue contribution to the Royal Government.

c) Contribute to socio-economic development.

d) Ensure domestic electricity supply security and reliability.

e) Ensure that the hydropower development is in accordance with the sustainable development policy of the Royal Government, keeping in view the fragile mountain ecosystem of the country.

f) Contribute towards development of clean energy to mitigate problems related to global warming and climate change.

Listed under the Institutional Arrangements of the Hydropower Sector in this policy document, DGPC is responsible for managing all hydropower plants fully owned by the Royal Government. It will also develop projects on its own, through joint ventures on behalf of the Royal Government as may be directed. The policy document stipulates that projects funded through bilateral assistance shall continue to be managed and supervised by the MoEA through formation of project authorities. Such fully Government-owned generating plants shall be handed over to DGPC when the Project Authority is dissolved.

4.2.16 Water Resources Management Plan 2003

The Water Resources Management Plan formulated in 2003 provides the general assessment of water resources in the country and addresses its present and future supply and demand scenarios. Water-related issues, including conflicts of water use, are highlighted and made aware in the Plan. Integrated water projects are also identified for possible sustainable development and demonstration.

4.3 Rules and Regulations

4.3.1 Regulation for the Environmental Clearance of Projects 2002

Under the regulation, both the National Environment Commission Secretariat (NECS) and the designated Competent Authorities (CA), which are listed in Annex 2 of the Regulation, are authorized to issue Environmental Clearances for projects.

Environmental Assessment consists of all procedures required under Bhutanese law to identify means to ensure that the activities of a project are managed in an environmentally sound and sustainable way.

As per Section 31 of this regulation, public consultation is mandatory. The applicant must explain to the affected people the expected impacts of the development, where they will occur and how they will be mitigated. It is also required to provide a record of the meeting/s and attach a list of the names of the people together with the date of consultation/s, details of their Geog and village, issues raised by them and the agreement/s arrived at between the applicant and the people to resolve these issues. It is required to provide signatures or other proof of consultation/s with the affected people. Residual (unresolved) issues are also to be noted.

The applicable time limit that will be required to obtain environmental clearance is provided in the table below.

Table 4-1: Applicable time limits to obtain environmental clearance.

Works	Time limits
Response by National Environment Commission Secretariat on the receipt of application. This is simply an acknowledgement of the receipt of the application.	Within 15 days
Review by the Secretariat to assess the adequacy of the application as per government rules and guidelines.	30 – 90 days
Decision/Response on the environmental clearance, based on the findings of the Environmental Assessment report.	30 – 90 days
Public notification on decision by the Secretariat/Competent Authority.	Within 15 days
Appeal on decision by public.	Within 30 days
On approval of the clearance, a legal undertaking with the proponent of new projects to comply with the EA Act, 2000.	10 – 30 days
Maximum time required to get EC	**270 days**

4.3.2 Forest and Nature Conservation Rules 2006

The Forest and Nature Conservation Rules of Bhutan, 2006 came into force with effect on September 1, 2006 and supersedes all relevant rules and regulations, notifications, circulars and instructions existing as of August 31, 2006. The rules are structured as follows: Chapter III describes regulations related to Government Reserved Forests; Chapter IV describes regulations related to Social and Community Forestry; Chapter V describes regulations related to Transport and Trade of Forest Produce; Chapter VI describes regulations related to Protected Area Management; Chapter VII describes regulations related to Wildlife Conservation; Chapter VIII describes regulations related to Soil and Water Conservation; Chapter IX describes regulations related to Enforcement and Penalties; Chapter X describes regulations related to Supply of Subsidized Timber for Rural House Construction, Repair/Renovation/Extension and Other Rural Purposes; Chapter XI describes regulations related to Supply of Other Forest Produce in Rural Areas.

As per Chapter II on Forest Management Planning and Plan Implementation under this act, the ministry shall issue administrative responsibility to the Department of Forests for the preparation

and adoption of management plans with regard to various types of forests. For government reserved forests, all forests (as defined in the Act) in Bhutan as of the effective date of these rules are declared to be Government Reserved Forests. Chapter III describes the procedure to allot land from the Government Reserved Forest to Government Institutions. The following activities are prohibited in Government Reserved Forests, except permitted by the Department, in an emergency or in compliance with any applicable Forest Management Plan for the area:

1) Disposal of any waste or pollutants in a water source or watercourse, or undertaking any other activity that may pollute a water source or watercourse;
2) Blockage, storage, disturbance or diversion of any river, stream, irrigation channel, waterfall, underground water source or any other water source or watercourse;
3) Fire burning including camp fires that may damage, destroy, or endanger trees, wild plants and animals;
4) Burning lime or charcoal or conducting any other manufacturing process;
5) Using dynamite or other explosives for any purpose;
6) Taking up permanent or long-term residence;
7) Destruction, damaging, or defacement of any structure, fence, marker, dam or anything else constructed, placed or planted by the Department or under the direction of the Department;
8) Marking or felling of trees within 600 feet uphill and 300 feet downhill of any motor road, except forest road (Section 14 (a) (i, ii, iii of Act, 1995). If the land is flat, felling is restricted within 300' on either side of any motorable roads, except forest roads and farm roads;
9) Marking or felling of trees within 100 feet of the bank or edge of any river, stream, and watercourse or water source;
10) Felling or marking trees within a river buffer;
11) Felling any tree without proper markings; and,
12) Felling and taking any timber from any place where the slope is greater than 45º unless authorized under an approved management plan or by the Head of the Department.

Fishing activity is described under Chapter III of these rules. It states that without possession of a valid fishing license, fishing /catching of fish in any stream, river, pond, or lake is strictly prohibited. The Department may declare certain rivers and lakes out of bounds for fishing.

Fishing License: A Fishing License shall be issued by the Department and/or an authorized Forest Officer of the area, as per Annexure 27 for one day and Annexure 43 for other than one day on payment of the prescribed fees as noted in Table 4-2.

Table 4-2: Fishing license charges.

Duration	Fee Nu.
one day	500.00
one month	1500.00
06 months	3000.00
01 year	5000.00

Restrictions:

1. Trout fishing shall be prohibited during the months of October, November and December every year.
2. Fishing of any type of fish is prohibited on 8th, 10th, 15th, 25th, and 30th, of each Bhutanese month. Fishing is also banned on the following religious occasions;

    i) Lhabab Dhuechhen.
    ii) Zhabdung Kuchhoe.
    iii) Yar-ngo and Mar-ngo Dhuezang.
    iv) Dukp Tshezhi or fourth day of sixth month of Bhutanese Calendar.
    v) Chhothhruel Dawa or the first month of Bhutanese Calendar.
    vi) Saga Dawa or the fourth month of Bhutanese Calendar.

3. Fishing by the following means is strictly prohibited:

    (a) Fishing by poisoning or using dynamite in rivers, streams, ponds or lakes.
    (b) Building dams for diverting rivers/streams to trap the fish.
    (c) Fishing by firearms, closed nets, large nets or splashing or laving of waters.
    (d) Fishing with live bait, traps and snares.

Catching trout, which are less than eight inches in length, is strictly prohibited. If caught, the fish should be released back into the water.

4.3.3 Building Rules of Bhutan 2002

The tenets of the rules are:

- To facilitate and regulate a functional and safe building construction.
- To promote a healthy living environment.
- To encourage a professional approach to building design and construction.
- To preserve and promote traditional architecture.
- To promote awareness of basic minimum design standards and procedures.

4.3.4 Rules on Biological Corridors 2006

This was promulgated in July 2007 as an addendum to the Forest and Nature Conservation Rules 2006. The following are the relevant points:

- The status of the biological corridors will be lower than that of the protected areas, but above government reserved forest.
- Based on the above status, the management of biological corridors shall be governed by the "Rules on Biological Corridors".
- The field level management of biological corridors shall rest with the territorial divisions under the Department of Forest and Park Services, who will also prepare a management plan.

4.3.5 Rules and Regulations on Explosives 1989

As the project will require a large quantity of explosives these rules and regulations are very important, particularly pertaining to import, transportation, and handling of explosives. The Bureau of Law and Order under the Ministry of Home and Cultural Affairs is the custodian of these rules and regulations.

The end-users of explosives must strictly abide to the requirements for transporting, handling, using, and storing explosive materials, to avoid unnecessary complication and untoward incidents in the future. With regard to the destruction of dead explosive materials, the concerned agency must carry out the destruction task in a scientific and eco-friendly manner, with a technically competent person, in a safe place with adequate safety measures, after obtaining necessary approval from the concerned authority.

4.3.6 Rules and Regulations on Occupational Health and Safety 2006

The purpose of the OHS Rules and Regulations is to assure safe and healthful working conditions for working men and women, as well as other persons present at workplaces, and protect them from work-related risks to their health, safety, and well-being. The rules apply to all employers and workers (both Bhutanese and non-Bhutanese) of licensed manufacturing, mining and service

enterprise, construction companies, bodies corporate incorporated under the Companies Act 2000 of the Kingdom of Bhutan, and any other agency employing large numbers of workers at the work site. Annexure II describes Minimum Safety Standards for the Construction Industry. This includes personal protective and life-saving equipment, fire protected hand and power tools, signs, signals and barricades, material handling, storage, use and disposal, scaffolds, excavations, electrical works, sanitation, and hygiene.

4.3.7 Waste Prevention and Management Regulation 2012

The regulation came into effect on April 18, 2012. The relevant points of the regulations are:

- establish procedures to implement the purpose of the Waste Prevention and Management Act, 2009;
- identify roles and areas of implementation of the Implementing Agencies for the purpose of establishing a sound waste management system, including monitoring procedures at every organization level, through efficient collection, segregation, treatment, storage, transportation, reduction, reuse, recycling and safe disposal of solid, liquid and gaseous wastes;
- assign costs in proportion to the waste volume generated from the point source or by degree of their hazardousness by levying fees, charges, and fines for non-compliance; and,
- control and prohibit illegal dumping or releasing of waste into the environment.

4.4 Summary of Applicable Laws

A summary of the regulations that apply to the NHPP during the construction and operation phases of the project is given in Table 4-3.

Table 4-3: List of applicable acts and regulations for NHPP.

Acts/ Regulations	Construction Phase	Operation Phase
The National Environment Protection Act 2007	Y	Y
Forest and Nature Conservation Act 1995	Y	Y
Biodiversity Act 2003	N	N
EA Act 2000	Y	Y
Land Act 2007	Y	N
Mines and Minerals Act 1995	Y	N

Road Act 2004	Y	Y
Bhutan Electricity Act 2003	Y	Y
Strategy for air quality assessment and management in Bhutan	Y	Y
Waste Prevention and Management Act of Bhutan 2009	Y	Y
Local Government Act of Bhutan	Y	Y
Regulation for the Environmental Clearance of Projects 2002	Y	Y
Forest and Nature Conservation Rules 2006	Y	Y
Rules on Biological Corridors 2007	Y	Y
Rules and Regulation on Explosives 1989	Y	Y
Rules and Regulations on Occupational Health And Safety (OHS) 2006	Y	Y

4.5 Applicable Guidelines and Standards

A number of guidelines and standards have been notified or issued by line ministries and departments in Bhutan in order to ensure compliance. The guidelines and standards relevant to the current project are noted below.

4.5.1 EA Guideline for Hydropower 2004

These guidelines have been prepared for simplifying the procedure for environmental clearance of hydropower projects, by addressing the requirements of the EA Act 2000 and Regulation for the Environmental Clearance of Projects 2002. Where hydropower projects will need to be constructed to generate power, the applicant will need to submit a separate application for environmental clearance in line with these guidelines.

4.5.2 EA Guideline for Transmission and Distribution 2004

These guidelines have been prepared for simplifying the procedure for environmental clearance of electricity transmission and distribution projects by addressing the requirements of the EA Act 2000 and Regulation for the Environmental Clearance of Projects 2002. Where transmission lines will need to be constructed to export power, the applicant will need to submit a separate application for environmental clearance in line with these guidelines.

4.5.3 EA Guideline for Highways and Roads 2004

These guidelines have been prepared for simplifying the procedure for environmental clearance of road projects by addressing the requirements of the EA Act 2000 and Regulation for the Environmental Clearance of Projects 2002. The applicant will be required to submit a separate application for access and internal road construction in line with these guidelines.

4.5.4 Environmental Assessment Guidelines for Mines 2004

These guidelines have been prepared for simplifying the procedure for environmental clearance of mines, mining areas, and mine lease projects by addressing the requirements of the EA Act 2000 and Regulation for the Environmental Clearance of Projects 2002. The applicant will be required to submit a separate application in line with these guidelines.

4.5.5 Environmental Discharge Standard 2010

National ambient air quality standards establish upper limits on the concentration of air pollutants in outdoor air, for the protection of human health, agriculture, natural vegetation and ecosystems, and the environment in general. These standards are shown in Table 4-4. Table 4-5 shows motor vehicle emission standards, while Table 4-6 shows the environmental standards for noise.

Table 4-4: Ambient air quality standards (maximum permissible limits in µg/m^3), NECS Bhutan.

Parameter	Industrial Area	Mixed Area*	Sensitive Area**
Total Suspended Particulate Matter			
24 Hour Average	500	200	100
Yearly Average	360	140	70
Respirable Particulate Matter (PM 10)			
24 Hour Average	200	100	75
Yearly Average	(World Bank/WHO = 150)	60	50
	120		
	(World Bank/WHO = 70)		
Sulfur Dioxide			
24 Hour Average	120***	80	30
Yearly Average	80	60	15

Parameter	Industrial Area	Mixed Area*	Sensitive Area**
Nitrogen Oxides			
24 Hour Average	120	80	30
Yearly Average	80 (World Bank/WHO = 40)	60	15
Carbon Monoxide			
8 Hour Average	5,000	2,000	1,000
1 hour Average	10,000	4,000	2,000

* **Mixed Area** means an area where residential, commercial, or both activities take place.

** **Sensitive Area** means an area where sensitive targets are in place, like hospitals, schools, sensitive ecosystems.

*** Exceeds (better than) WHO/World Bank guidelines.

Table 4-5: Motor vehicle emission standards.

Fuel Type	Vehicle registered prior to Jan 1, 2005	Vehicle registered after Jan 1, 2005	Type Approval
Petrol (%CO)	4.5	4	Euro-II
Diesel (%HSC)	75	70	

Table 4-6: Environmental standards for noise.

Land Use Category	Maximum Level	
	Day	Night
Industrial Area	75 db	65 db
Mixed Area	65 db	55 db
Sensitive Area	55 db	45 db

Noise standard as per land use Category 2. World Bank noise guidelines are 70 db day and night for industrial areas, and the same as Bhutan guidelines for sensitive areas.

4.5.6 Land Compensation Rates 2009

The Land Compensation Rates 2009 came into effect on May 1, 2009. These cover compensation for land and structures falling both within urban and rural areas when acquired by the government.

For rural areas, the land is categorized into four classes: 1) Kamzhing (dryland); 2) Chhuzhing (paddy land); 3) Ngultho Dumra (cash crop land); and, 4) Class A1 (close to Throme). For urban areas, compensation is different for each class of Throme. The document also provides implementation procedures.

4.6 Institutional Framework

Bhutan is a Constitutional Monarchy, which has three arms of government: the Legislative; the Executive; and, the Judiciary, each functioning independently. The King of Bhutan is the Head of State. The National Assembly is the highest legislative body and the executive power is vested in the cabinet. The government is represented by an elected cabinet (Lhengye Zhungtshog). The chairman of the cabinet is the Prime Minister. The central government is represented by ten ministries and the autonomous agencies. At the sub-national level, the country is administered through 20 dzongkhags (districts). The dzongkhags are sub-divided into geogs; there are 201 geogs (blocks). If the dzongkhag size is large, dungkhags are created for easy administration. The country's administration was decentralized in 1991 through the establishment of Dzonkhag Yargay Tshogchungs (DYTs), followed by the Geog Yargay Tshochungs (GYTs). The decentralization policy of the government is further reinforced with a focus on geog-based planning. Figure 4-1 shows the Bhutanese system of governance. A description of various institutions is given in the following sections.

National Environment Commission Secretariat: The National Environment Commission Secretariat is an autonomous body serving and providing advisory services to the Royal Government on matters pertaining to the environment. This Commission is entrusted with the mandate to meet its long-term objective of defining policies, plans and actions whereby the sustainability of natural resources will be fully integrated into every aspect of Bhutan's social and economic development. The NEC is also responsible for implementation of national environmental issues and focal agency for international environmental conventions. The NEC is the custodian of the EA Act 2000.

Department of Hydropower and Power System (erstwhile Department of Energy): The Department of Hydropower and Power System within the Ministry of Economic Affairs is responsible for the power sector policy, planning, and regulations. In addition, the Department is also responsible for generation, distribution, transmission, investigation and implementation of

various projects. One of the main objectives of the department is the creation of an enabling environment through formulation of hydropower policy guidelines to encourage possible participation of independent power producers and operators.

Department of Forests and Park Services: The Department of Forests and Park Services (DOFPS), under the Ministry of Agriculture and Forests, is entrusted with the responsibilities of the management of the forest resources and biodiversity. The primary focus of the DOFPS is to ensure that at least 60% of the country's area is maintained under forest cover at all times, and to conserve the rich biological diversity through the establishment of an effective network of Protected Areas. All projects that infringes into forestland have to seek clearance from this department.

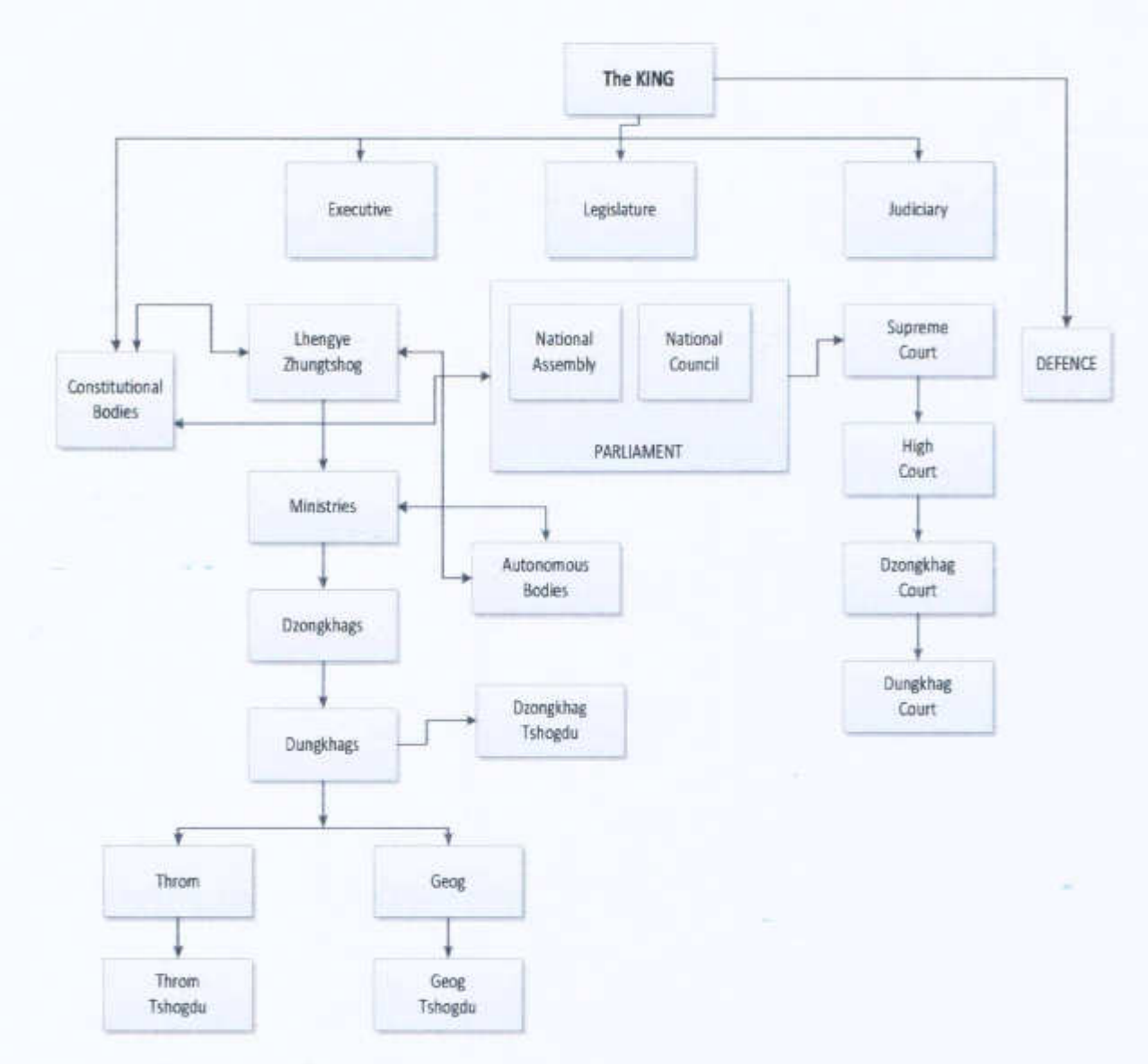
Department of Geology and Mines: The Department of Geology and Mines (DGM) is responsible for surveying, planning, investigation, implementation of mineral explorations, and monitoring of glacial lakes and outburst threats. The Department is the custodian of the Mines and Mineral Management Act 1995. DGM issues clearances for the quarry sites.

Department of Roads: The Department of Roads (DoR) has the mandate to plan and construct the road network in the country. The department is the custodian for the implementation of the Road Act 2004. The construction of access roads to a hydropower site needs to seek clearance from the Department of Roads (this needs to be attached when applying for EC).

Bhutan Power Corporation: The Bhutan Power Corporation was separated from the former Department of Power with a mandate not only to ensure availability of electricity to all citizens but in a reliable, adequate and affordable manner for all consumers.

Trongsa Dzongkhag: Administratively, Trongsa Dzongkhag is divided into five Geogs. These Geogs have their own administration headed by Gups (geog administrators). With the implementation of new GYT Chathrim since 2004, Gups are now directly elected by the people. These elected Gups are members of the DYT and the chair of the DYT is elected amongst them. In the DYT, the Dzongdag (District Administrator) only has an observer status. As the project falls within this Dzongkhag, the project will have to coordinate very closely in the process of its implementation.

Figure 4-1: Governance system in Bhutan.



4.7 Procedure for Environmental Clearance and Required Compliances

The procedure for environmental clearance for hydropower projects follows a three-stage process as shown in Figure 4-2. This procedure is in line with the EA guidelines for hydropower projects. In order to obtain an Environmental Clearance for the project, a No-Objection-Certificate (NOC) must be obtained from all relevant agencies. Table 4.7 (below) is a checklist of agencies from whom NOCs may be required for the NHPP.

Table 4-7: Checklist of compliances required for NHPP.

Agency/Concerned People to Issue NOC	Why/ When	Requirement for NHPP (Dam/ HRT/TRT/PH)
Dzongkhag/City Corporation	Administrative Approval from Dzongkhag	N
DoFPS	Should the project damage or acquire Tsamdo	N
DoFPS	Should the project damage or acquire Sokshing	N
Department of Culture	Should the project be located within 50 m of a cultural or religious site	N
Nature Conservation Division	Within boundary of a Protected Area	Y
Municipal Authority	Within 50m of public park	N
Private Owner	Within 50 m of a human dwelling	N
Private Owners	Should the project need to acquire private property	Y
Department of Health	Within 50 m of a hospital	N
Department of Education	Within 50m of a school	N
Department of Energy	Should the project require the relocation of a power transmission l i ne	N
Bhutan Telecom Authority	Should the project require relocation of telephone lines	N
Department of Roads	Should the project require access from highways and feeder roads	Y

Note: Y- Yes and N- No

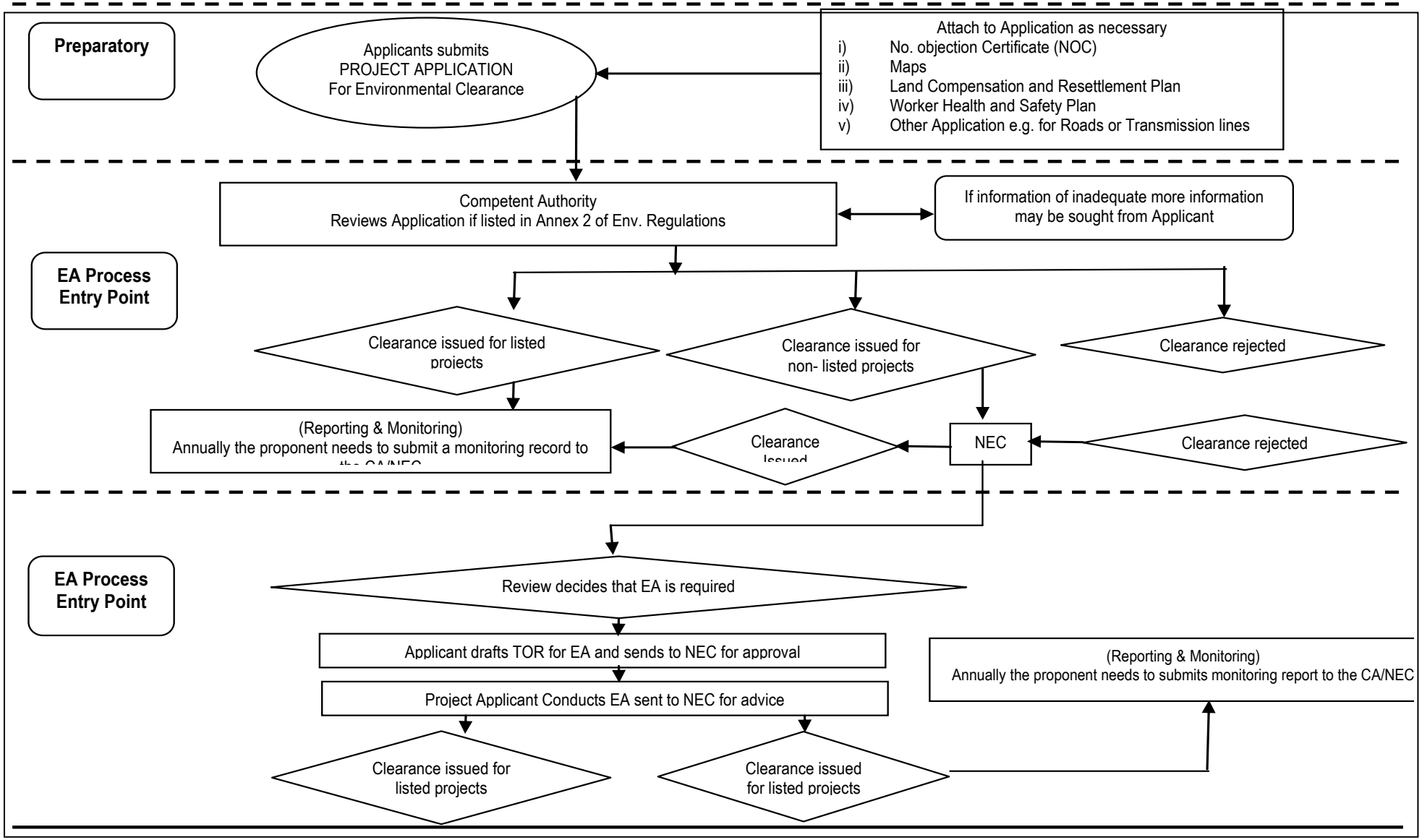


Figure 4-2: EA process.

4.8 International Commitments

The Royal Government of Bhutan is well-represented in the international and regional environmental arena as part of its commitment to environmental conservation and protection. The National Environment Commission Secretariat, as a key environmental policy making body/ nodal agency of the country, participates in various international meetings relating to conventions and agreements that Bhutan has signed or ratified. Bhutan is party to Multilateral Environmental Agreements as noted below:

1. UN Framework Convention on Climate Change signed on 11th June 1992; Instrument of Ratification signed on 25th August 1995.
2. UN Convention on Biological Diversity signed on 11th June 1992; Instrument of Ratification signed on 25th August 1995.
3. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); Instrument of Accession signed on 2nd August 2002; ratified in 2004.
4. Kyoto Protocol to the United Nations Framework Convention on Climate Change; Instrument of Accession signed on 26th August 2002, and now a member, after Kyoto came into force in 2005.
5. Cartagena Protocol on Biosafety (the Convention on Biological Diversity).
6. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal; Instrument of Accession signed on 26th August 2002; Bhutan became a party in 2004.
7. UNESCO World Heritage Convention; Instrument of Ratification signed on 10th October 2001.
8. International Plant Protection Convention (Adherence); came into force for Bhutan on 20th June 1994.
9. The Final Act and the Law of Sea Convention; signed on 10th December 1982.
10. Statute of the Centre for Science and Technology of the Movement of Non-Aligned Countries and other Developing Countries; signed on 4th February 1985.
11. Statutes of the International Centre for Genetic Engineering and Biotechnology; signed on 31st May 1984; Instrument of Ratification signed on 15th April 1985.
12. Vienna Convention for the Protection of the Ozone Layer; acceded in 2004; Montreal Protocol on Substances that Deplete the Ozone Layer; signed in 2004.

13. United Nations Convention to Combat Desertification (UNCCD); signed in 1992; ratified in 2004.

The domestic regulatory environment and compliance framework show the commitment of the country, not only to international conventions, but also to plan and implement measures for environmental conservation and protection.

4.9 ADB Safeguards Policy Statement 2009

The Safeguard Policy Statement (SPS) builds upon the three previous safeguard policies on the environment, involuntary resettlement, and indigenous peoples, and brings them into one single policy that enhances consistency and coherence, and more comprehensively addresses environmental and social impacts and risks. The SPS aims to promote sustainability of project outcomes by protecting the environment and people from projects' potential adverse impacts by avoiding adverse impacts of projects on the environment and affected people, where possible. This involves minimizing, mitigating, and/or compensating for adverse project impacts on the environment and affected people when avoidance is not possible. The intention is to help borrowers/clients to strengthen their safeguard systems and develop the capacity to manage environmental and social risks. Specific directions are summarized below. This ESIA, the EMP, and RP are all consistent with the themes and instructions in the ADB Safeguards Policy Statement (it is intended to serve the needs of the Royal Government of Bhutan and the NEC, as well as ADB itself).

4.9.1 Safeguard Requirements

The safeguard policies require that: (i) impacts are identified and assessed early in the project cycle; (ii) plans to avoid, minimize, mitigate, or compensate for the potential adverse impacts are developed and implemented; and, (iii) affected people are informed and consulted during project preparation and implementation. The policies apply to all ADB-financed projects, including private sector operations, and to all project components.

4.9.2 Roles and Responsibilities

A basic principle of the three existing safeguard policies is that implementation of the provisions of the policies is the responsibility of the borrower/client. Borrowers/clients are required to undertake social and environmental assessments, carry out consultations with affected people and communities, prepare and implement safeguard plans, monitor the implementation of these plans, and prepare and submit monitoring reports. ADB's role is to explain policy requirements to borrowers/clients, help borrowers/clients meet those requirements during project processing and implementation through capacity-building programs, ensure due diligence and review, and provide

monitoring and supervision. Considerable attention is devoted to the project processing and approval phase of the project cycle, although ADB's role in monitoring safeguard compliance continues during project implementation. ADB's project completion reports and project performance evaluation reports include review of the implementation of safeguards.

4.9.3 Compliance System

ADB has established arrangements for monitoring projects' compliance with its safeguard policies. With the support of the Environment and Social Safeguard Division, ADB's Chief Compliance Officer is responsible for advising management and operations departments on safeguard compliance and related operational procedures and guidelines. Compliance with the safeguard policies is monitored throughout the project cycle. If a project poses risks of noncompliance, actions to ensure compliance are recommended at the Management Review Meeting, and project compliance is reviewed again at a Staff Review Committee meeting. Operations departments take steps to ensure that outstanding safeguard requirements are met before Board approval.

4.9.4 Accountability Mechanism

ADB adopted an accountability mechanism whereby people adversely affected by ADB-financed projects can: express their grievances; seek solutions; and, report alleged violations of ADB's operational policies and procedures, including safeguard policies. ADB's accountability mechanism comprises two separate, but related, functions: (i) consultation, led by ADB's special project facilitator, to assist people adversely affected by ADB-assisted projects in finding solutions to their problems; and, (ii) providing a process through which those affected by a project can establish acceptable solutions to their individual issues.

5 BASELINE ENVIRONMENTAL AND SOCIO-ECONOMIC INFORMATION

5.1 Introduction

The environmental and social (including socio-economic) impact assessment is focused on possible changes to the existing (or baseline) environmental and socio-economic features within the zone of influence of the Nikachhu Hydropower Project (pre-construction, during construction, and during operation). This requires a sound understanding of the spatial and temporal features of the existing conditions in and near the project area, and their vulnerabilities, recovery potential, and relative importance in the overall context of Bhutan and the sub-region. This chapter therefore provides information on the baseline environmental and socio-economic conditions in and near the Nikachhu project area, based on primary data (from field surveys over the last two years; specific methodologies are discussed where relevant) and secondary data (accessible reports and the scientific literature for Bhutan).

The baseline survey area was defined in the following manner: the project "footprints" (for all project components) were mapped, using existing topographic and land use charts, and survey points and transects (for physical features, and aquatic and terrestrial ecology) were then defined to ensure that representative features within the individual footprints would be picked up in the surveys (see the various annexes for locations of field surveys). This distribution of field survey effort ensured that the specific project sites and the zones of influence of various project components (usually confined to 200-300 metres, given the nature of the project) could be properly described, allowing sound environmental impact assessment. Furthermore, satellite images (GoogleEarth) were examined to extrapolate the observed field conditions, as necessary, to all the areas between the survey transects, especially where continuity of habitat was evident. For example, forest type could be observed and species composition defined based on field surveys, and then this information could be extrapolated to other areas, based on the similarities observed in the satellite images, giving a high degree of confidence to the field data. Similarly, the cascade and waterfall areas that were observed in the field, and corroborated in the satellite images, allowed determination of the location and scale of waterfalls at other points on the Nikachhu, which could not otherwise be accessed during the field surveys. In this manner, all areas that are expected to be affected by the Nikachhu project could be properly categorized for impact assessment.

The main field surveys were undertaken in July and October 2012 (for terrestrial ecology features) and July and December 2012 (for aquatic ecology). Additional field verifications were undertaken in May 2013, and the proposed transmission alignment was surveyed in detail in September-October 2013 (walk through survey) and December 2013 (terrestrial ecology survey). These survey periods generally picked up the main seasonality in the area (early monsoon and post-monsoon), in order to give some confidence in applicability of the survey data to a typical annual cycle. In any case, the

field database will build up over the project construction and operation phases, as monitoring of key aquatic and terrestrial ecology features is proposed (in each quarter, or semi-annually, depending on the parameter, over at least 3-4 years). This monitoring will, in fact, give a more detailed understanding of the natural features of the area, compared to surrounding unsurveyed areas. These data will be very useful as input to planning and management of the adjacent Jigme Singye Wangchuck National Park.

The baseline information is arranged in the following order: a) physical environment (including chemical characteristics, where relevant); b) biological features (which depend on and reflect the physical environment); and, c) the socio-economic aspects of communities living in and near the project area (which tend to reflect both physical and biological conditions in the area). The focus in the baseline description is on the specific features which may be vulnerable to the Nikachhu project, to ensure that they are properly considered and inform the impact assessment and development of appropriate and effective mitigation measures (presented in Chapter 6).

5.2 Physical Environment

5.2.1 Introduction

The physical environment of the Nikachhu project area and environs includes the overall location within Bhutan, topography, geology (and seismicity), land use, climate, hydrology and the various features specific to air and water. Land use and localized topography, air quality, and water parameters are potentially vulnerable to changes caused by the Nikachhu project, whereas all physical features potentially influence how the project design, construction, and operation will proceed (impact of the environment on the project).

5.2.2 Location

The Nikachhu Hydropower Project is located in Trongsa Dzongkhag, which is located in Central Bhutan at latitude 27.5° North and longitude 90.5° East, with Bumthang Dzongkhag to the northeast, Wangdue Phodrang Dzongkhag to the west, and Sarpang and Zhemgang Dzongkhags to the south (Figure 5-1). The district covers an area of about 1,807.29 sq. km, and is subdivided into five geogs (Drakteng, Korphu, Nubi, Langthel, and Tangsibji). The main administrative centre is Trongsa town, which is approximately 150 km east of the national capital, Thimphu. Trongsa Dzongkhag has a total 2,789 households with a total population of 13,419 (PHCB, 2005).

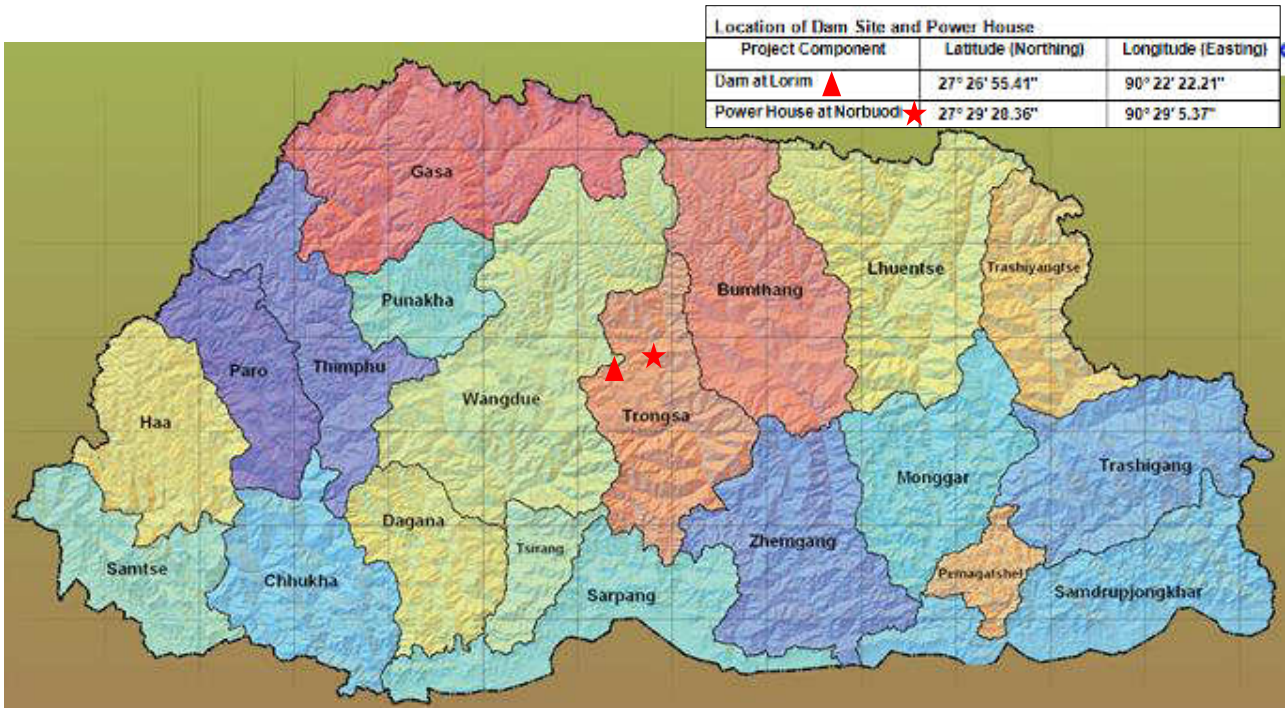


Figure 5-1: Location of Nikachhu Hydropower Project.

5.2.3 Topography, Geology, Soils, and Seismicity

The topography of the project area is rugged and the valleys of the Dzongkhag are deeply cut, with steep convex side slopes and narrow V-shaped valley floors, caused by swift-flowing rivers like the Mangdechhu, and the Nikachhu itself. The elevation of the Dzongkhag ranges from 1,200 m to 4,800 m above sea level (asl), but most settlements are situated closer to the valley floors and at mid-level altitudes up to 3,000 m (Atlas of Bhutan, 1997). The elevation at the proposed dam site for the Nikachhu project is about 2,260 masl, rising about 100 meters up to the National Highway. The intense tectonic activity that resulted from the collision of the Indian and Eurasian continental plates, the closure of the intervening Tethys Ocean, and the uplift of the Himalayas are responsible for the topography and geology of Bhutan. The project area falls in the zone of predominant north-south valleys and ranges, with smaller east-west river system cuts, where the bedrock comprises mostly gneiss, schist, quartzite, and limestone, with intrusions (Norbhu *et al.*, 2003).

The whole project area was surveyed on foot. The topographic gradient was measured in the field using a SUUNTO Clinometer (allowing reading of graduations either in percentages (%) or degrees). The SUUNTO reading was also cross-checked with a profile plotted on the GoogleEarth Map (which shows the elevation profile). The Google-plotted profile also shows maximum and average gradients. High ridges, steep slopes, deep gullies, and few lowlands characterize the topography of the specific project area (and most of Trongsa Dzongkhag, as noted above). The gradients measured for the different locations of specific project components are presented in Table

5-1a. The maximum gradients (near-vertical) are found at the proposed dam site at Lorim (the dam site is taking advantage of the steep river profile in this location). Figure 5-2 shows the distribution of the slope classes in the upper catchment and along the Nikachhu below the proposed dam site, reflecting steep slopes on the south side of the river, and more gradual slopes on the north side of the river. With the exception of the muck disposal site for Adit 1 and the camp site for the surge shaft (which have relatively low average slopes), most sites required by the project have average slopes in excess of 36%, and will require cuts to make level work areas (typical for construction in Bhutan).

Table 5-1a: Slopes measured at various project component locations.*

Project Component Location	Maximum Slope (%)	Average Slope (%)
From highway to dam site	56	36
Dam, JSW National Park side	98	37
Staff colony at dam site	83	49
Muck disposal site for Adit 1 (from dam site)	13	11
Muck disposal site for Adit 2	65	58
Muck disposal site for Adit 3	62	43
Muck disposal site for Adit 4	72	69
Muck disposal site for Adit 5	83	64
Temporary camp at power house	63	56
Camp site for surge shaft	50	13
Muck disposal site for surge shaft	81	63

** A vertical slope is a 100% slope.*

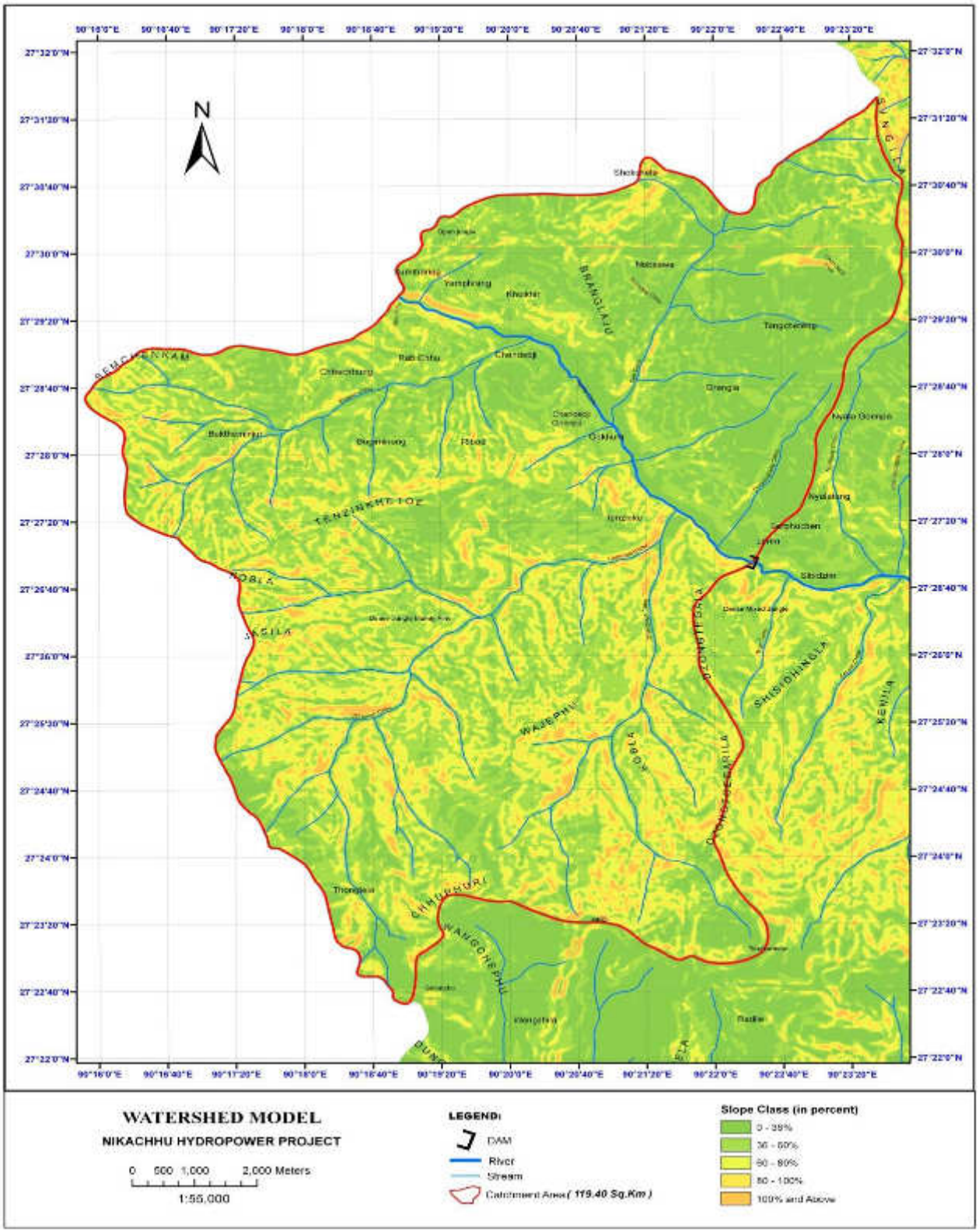


Figure 5-2: Distribution of slope classes in the Nikachhu upper catchment area (above the proposed dam).

The geological investigation was undertaken by Lahmeyer International (India) Pvt. Ltd. in July 2012. Seismic hazard mapping for the project is based on the work of the Indian Institute of Technology (Roorkee, 2009). The field survey also included mapping of existing landslide areas within the project area. In terms of geology, the project area lies in a central crystalline belt surrounded by the lithology of the Thimphu Gneissic complex (TGC) and the meta-sediments of the Chekha Formation. The riverbed geological investigation revealed that below 2 m under the riverbed, the granite bedrock was found to be highly stable. The proposed dam site lies in a narrow V-shaped valley. The northeast side (left bank) abutment is covered with dense vegetation over colluviums, having no bedrock exposure at all along the slope, except at the road level and the riverbed itself. The southwest side abutment (right bank) has prominent exposures of garnetiferous mica schist, from the riverbed up to higher elevations. The abutment slopes are nearly 500-600 meters high on the left bank and 600-700 meters high on the right bank. The surge shaft and powerhouse complex area is also located within garnetiferous micaceous schist. In between these two "ends" of the project, there is a gradation in geology that alternates between granite and granitic gneiss (see Table 5-1b; which also shows the compressive strength of the three types of rock, in megapascal; 1 MPa = 10.20 kg/cm^2).

Table 5-1b: Geological features along the tunnel layout of the Nikachhu HPP.

Component	Dam	HRT				Surge Shaft
Chainage	0+000 km	1+500 km	3+300 km	3+800 km	4+900 km	7+200 km
Rock Type	Garnetiferous Micaceous Schist	Granitic Gneiss	Granite	Granitic Gneiss	Granite	Garnetiferous Micaceous Schist
Compressive Strength (MPa)	25 – 50	25 – 100	50 - 100	25 - 100	50 – 100	25 – 50

Source: Kalachakra Consultancy, July 2012

In Bhutan, the soils produced by local base materials remain largely unmapped. In the valleys, surface layers consist mainly of alluvium brought in by the rivers, which deposit large quantities of sand and silt on the banks each year. The rivers and forested catchments produce soils that are high in organic material, and are mainly temperate stagnogleys and podzols (Norbhu *et al.*, 2003). Soils are generally sandy loam and clay loam, with good permeability and moderate moisture retention (DOFPS website). Forest soils are generally shallow. The topsoil in agricultural areas has a pH between 5 and 6, with loamy clay making up 10-30% content, and silt comprising 20-50%

(MPFD, 1991). The rugged terrain in the project area suggests that maintenance of vegetative cover and careful use of soils is necessary to check erosion and landslides.

The July 2012 survey recorded only one landslide between the dam site (at Lorim) and the power house at Norbuodi (see Figure 5-2; at Chipokto; coordinates of 27°28'40.42"N and 90°28'49.78"E). This landslide was created by quarry extraction by the Department of Roads for highway maintenance. Otherwise, the combination of geology, slopes, and quite heavy vegetation cover creates a consolidated terrain that is not apparently subject to natural landslides.

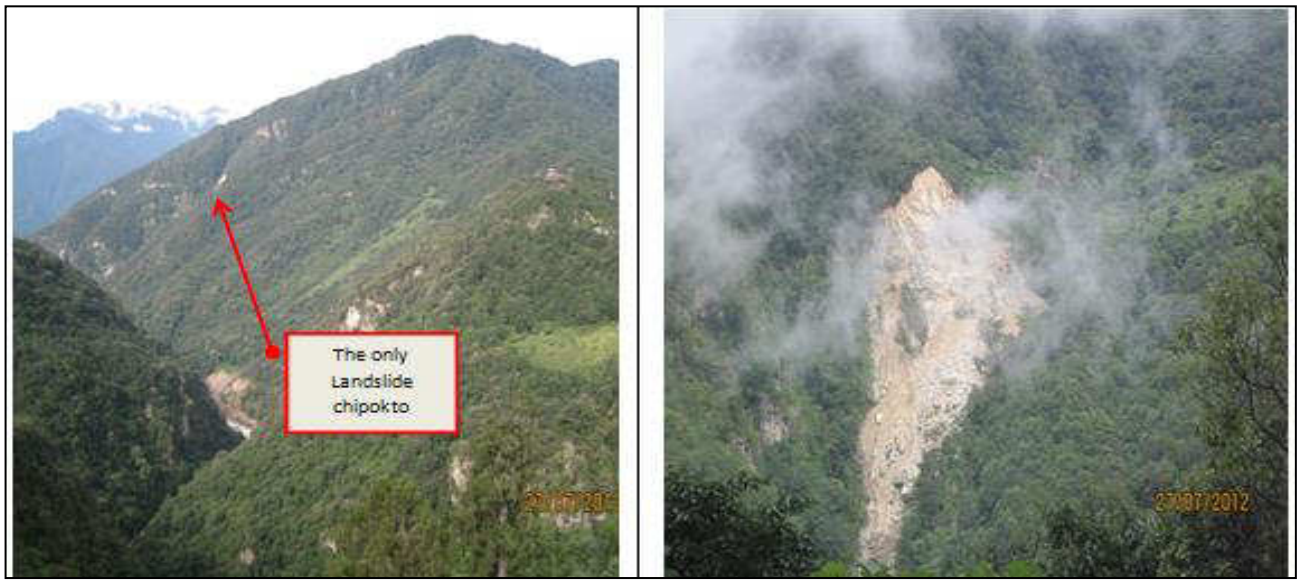


Figure 5-3: The only landslide recorded between the proposed dam site at Lorim and the powerhouse at Norbuodi.

The recorded seismic activity in the project area dates back to June 12, 1897, when the epicenter of an earthquake was 80 km south of Bhutan (in Rangjoli, Assam, India). In Bhutan, the earthquake destroyed Punakha and Lingzhi Dzongs, and damaged Wangdi, Trongsa, Jakar and Utse of Tashicho Dzong. The record of major earthquakes and their magnitude on the Richter scale is shown in Figure 5-4. Figure 5-5 is the seismic hazard map of Bhutan (prepared by the Indian Institute of Technology in Roorkee, India); it shows that the Trongsa area lies in a low hazard zone (rated in a 4-point scale of low to very high).

Figure 5-4: Recorded earthquake occurrence in and around Bhutan (location, date, and Richter scale measurement).

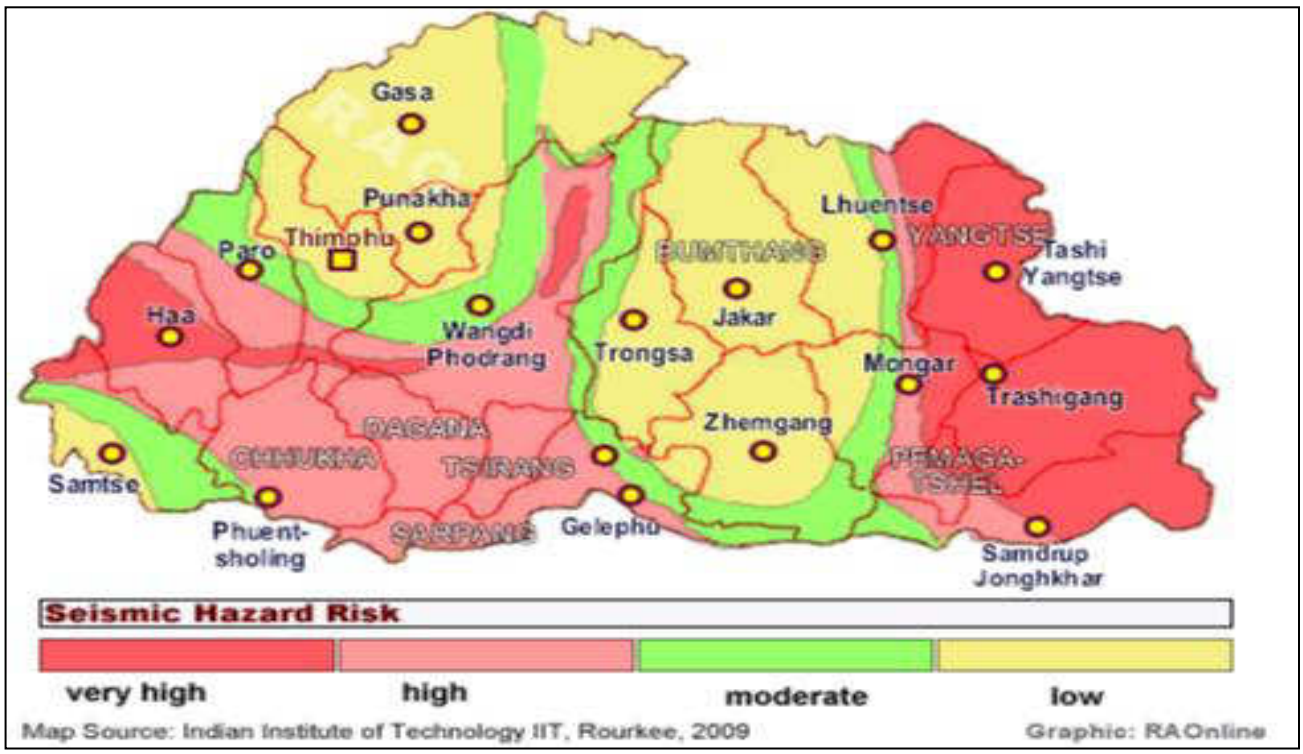


Figure 5-5: Seismic hazard risk for Bhutan.

5.2.4 Issue of reservoir induced earthquake and possible dam failure and downstream destruction

Gross reservoir capacity of the project is only 0.537 million m^3 with 0.046 km^2 of reservoir surface area at full reservoir level created by a 33 m high dam. The reservoir backflow stretches only about

800 m. This reservoir volume, compared with mean annual flow volume of the Nikachhu (505 million m^3) is only about 0.10%, which is very small. For the Sankosh reservoir hydropower project, the reservoir volume (3,920 million m^3) as compared with mean annual flow volume (15,220 million m^3) is about 26%, with a reservoir fetch of 45 km and reservoir surface area of 46.26 km^2. Presently, there are three hydropower reservoirs under operation namely: Chukha Hydropower Plant since 1986 (3.1 million m^3), Kurichhu Hydropower Plant since 2001 (15.7 million m^3) and Tala Hydropower Plant since 2006 (9.8 million m^3). The geological formation in the reservoir area of Nikachhu is competent to take the weight from the small reservoir volume. Based on the experience with existing hydropower plants and given the small size of the reservoir of the Nikachhu project, the risk of reservoir-induced seismic activity may be extremely small.

The Nikachhu dam will be a concrete gravity dam. The dam will be designed based on site specific seismic parameters which have been studied and determined by the Indian Institute of Technology, Roorkee, India as per the guidelines prescribed by the National Committee on Seismic Design Parameters (NCSDP), India. The institute is one of the two national institutes in India approved for such specialized studies. The site-specific seismic parameters consider the seismic zonation of the project area, geo-tectonic features, and large seismic events in the vicinity of the project area.

In the event of dam failure, a hazard zonation map downstream of the dam until its confluence with the Mangdechhu has been delineated. During the O&M stage of the project, as is being practiced in existing power plants, an emergency preparedness and mitigation plan will be developed and implemented for the safety of downstream settlements (it is included in the EMP). Even so, in the case of the Nikachhu, there is no human settlement downstream of the dam until its confluence with the Mangdechhu.

5.2.5 Land Use

5.2.5.1 Tangsibji Geog and the Nikachhu Catchment Area

Trongsa Dzongkhag has five Geogs (Blocks). The Nikachhu HPP is located entirely within the Tangsibji Geog. Land use in Bhutan is broadly categorized into eight sub-headings: 1) farming; 2) settlement; 3) privately managed pasture land (tsamdo); 4) rivers and streams; 5) roads; 6) forest for timber supply; 7) natural forest often grazed by livestock; and, 8) protected areas. In Tangsibji Geog, active land use includes some farming (including cultivation and pasture grazing), settlements (including roads), and access to rivers and streams. Land types and uses in Tangsibji Geog and the project area are described below. The land use map of Bhutan was the basis for determining land type and use areas in the Geog. Note that the depiction of land types (such as various kinds of forest, shown in the ARC GIS 9.2 database for Bhutan) does not automatically infer land use, as the satellite visual depiction of a forest, for example, does not readily clarify whether or

not that forest is used for economic purposes. Ground-truthing (with GPS) was conducted to tally observations with the land use map, to allow an allocation of land types and uses to the total Tangsibji Geog area.

Explicit land uses in Tangsibji Geog (farming, pasture, and settlements) comprise an extremely small percentage of the total land area; less than 2.5% of the total area, reflecting minimal development in this part of Bhutan. The agricultural land use in the upstream area of the Nikachhu and in the Geog is primarily dryland cultivation, focused on wheat, potatoes, and buckwheat. In some places, like Sephu and Rukubji, dryland cultivation constitutes only 1% of the Geog area, and as a result, people resort to cattle and yak rearing to support their livelihoods. Table 5-2 shows the land types and uses in Tangsibji Geog. Forests (broadleaf, coniferous, and scrub) make up 87% of the Geog area. The distribution of the land types and uses in the project area are shown in Figure 5-6. Most of the human uses of land in the project area are restricted to the area near the National Highway just southwest of Norbuodi and these are almost exclusively dryland cultivation areas. There is minimal overlap of the project component "footprints" and current human land use in the project area (discussed later).

Table 5-2: Land type/use of Tangsibji Geog as of July 2012 (source: GIS-verified land use map of Bhutan, 2012).

Land Use Type	Area (Acre)	Area (%)
Broadleaf Forest	32,372.55	35%
Coniferous Forest	37,699.42	41%
Dryland Cultivation	778.40	1%
Landslips / Erosion	156.86	0.2%
Mixed Cultivated	186.98	0.2%
Natural Pastures	7,401.03	8%
Rock Outcrops	665.23	1%
Scrub Forest	10,289.49	11%
Settlement	27.32	0.03%
Snow / Glaciers	1,141.11	1%
Tseri	15.56	0.02%
Water Spreads	77.08	0.08%
Wetland Cultivation	743.13	1%
TOTAL	**91,554.14**	**100%**

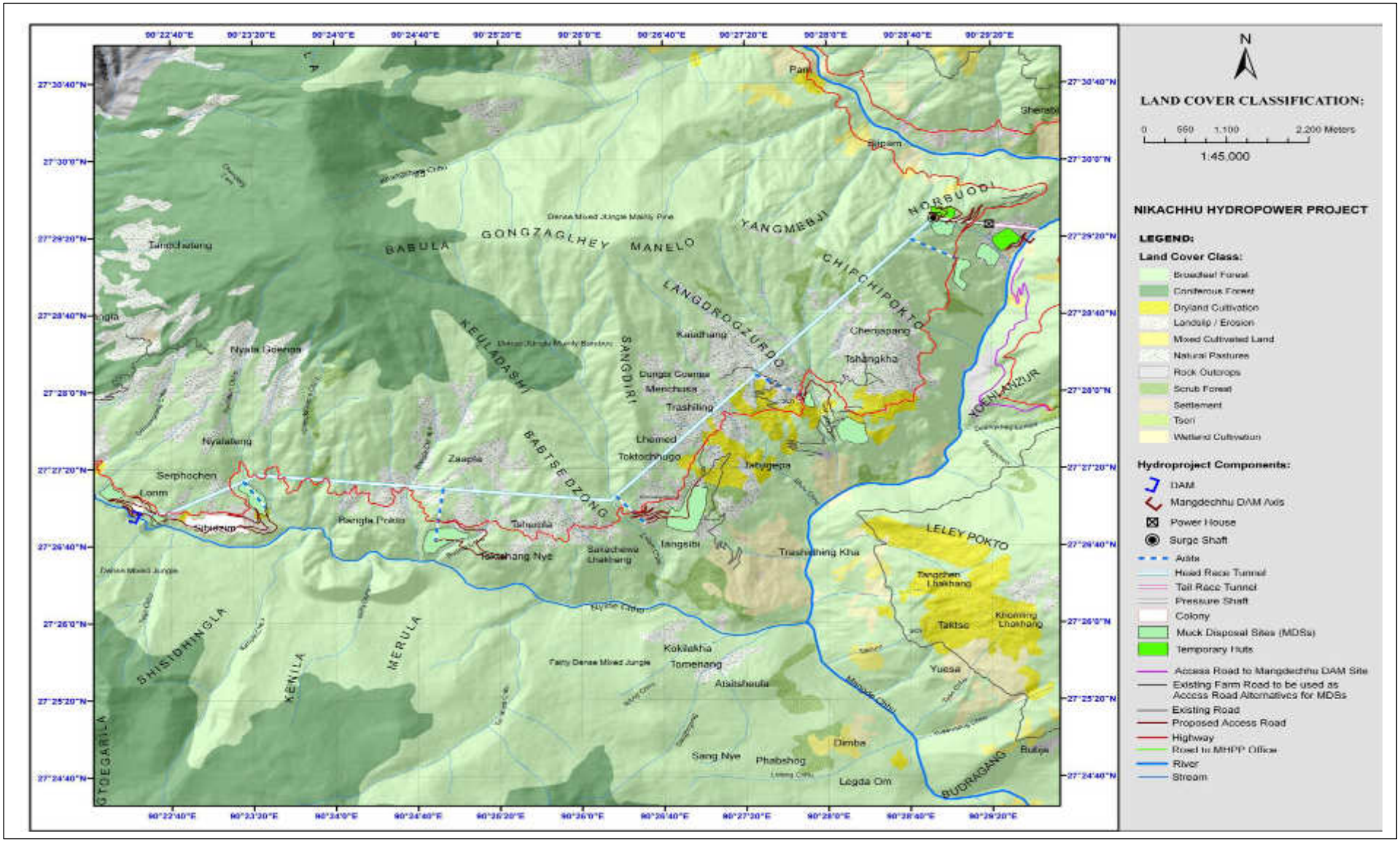


Figure 5-6: Land types and uses in Tangsibji Geog (as of July 2012).

5.2.5.2 Land Use along the Power Transmission Line

The power transmission line will be installed in the altitude range of 1,200 m to 2,300 m asl. The vegetation types found along the proposed alignment at this altitude include the broadleaf forest (mainly comprising *Quercus* species; oaks, and conifer forests, dominated by chirpine; the broadleaf forest makes up about 80% of the transmission line alignment). Where there is human activity, paddy and maize fields predominate (see Figure 5-7, which shows the land types and use along the proposed alignment of the transmission line). The actual footprint of the power transmission line will be quite small; restricted to the tower foundations. Figures 5-8 to 5-10 show the elevation and land use types along the proposed transmission line alignment. Agricultural land, community forest, and footpaths make up only 3% of the transmission line alignment. Most of the transmission line will be very close to the current line that runs from Trongsa to Yurmo.

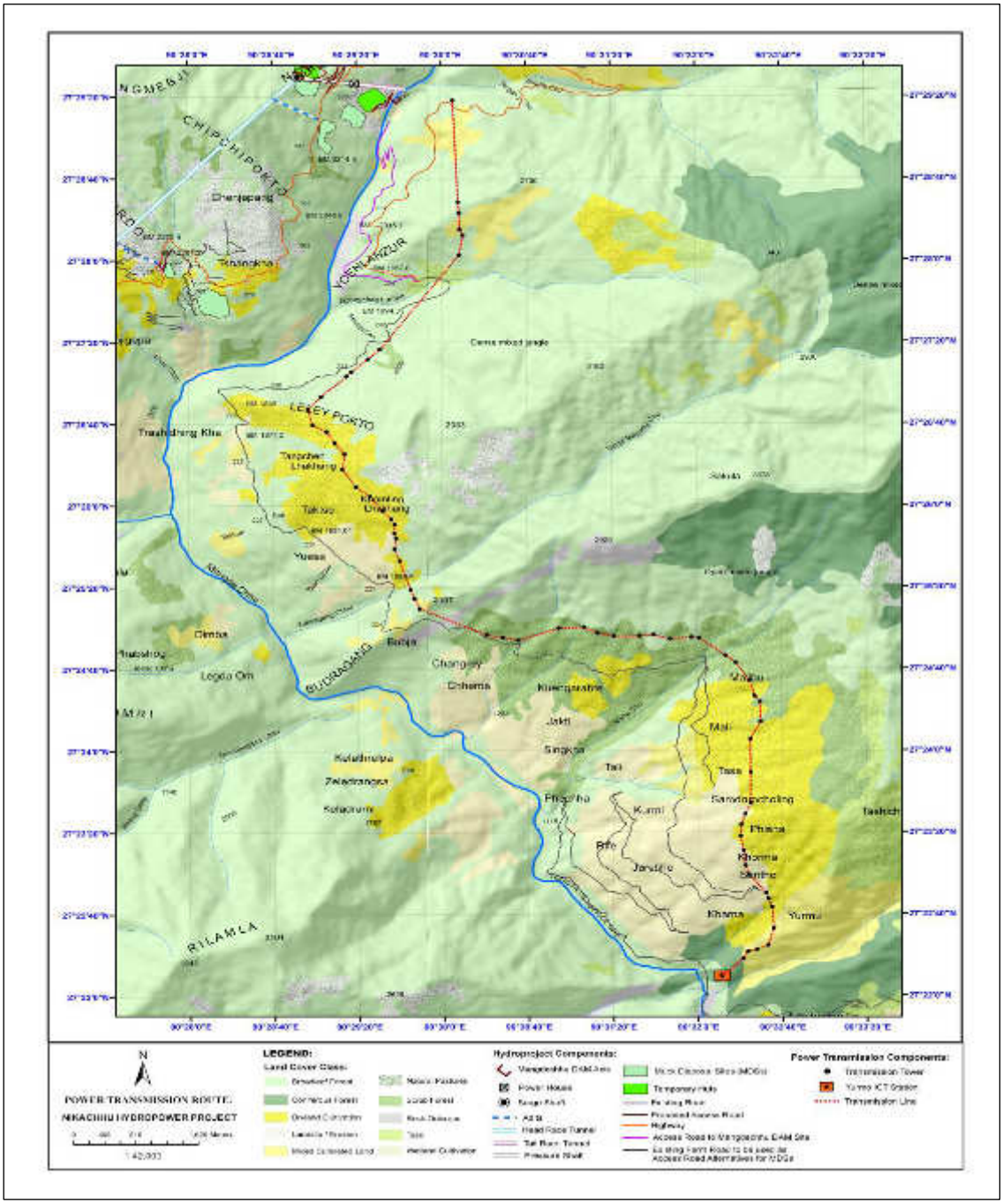


Figure 5-7: Land cover and land use along the proposed alignment of the power transmission line from the Nikachhu powerhouse to Yurmo (as envisaged in 2012).

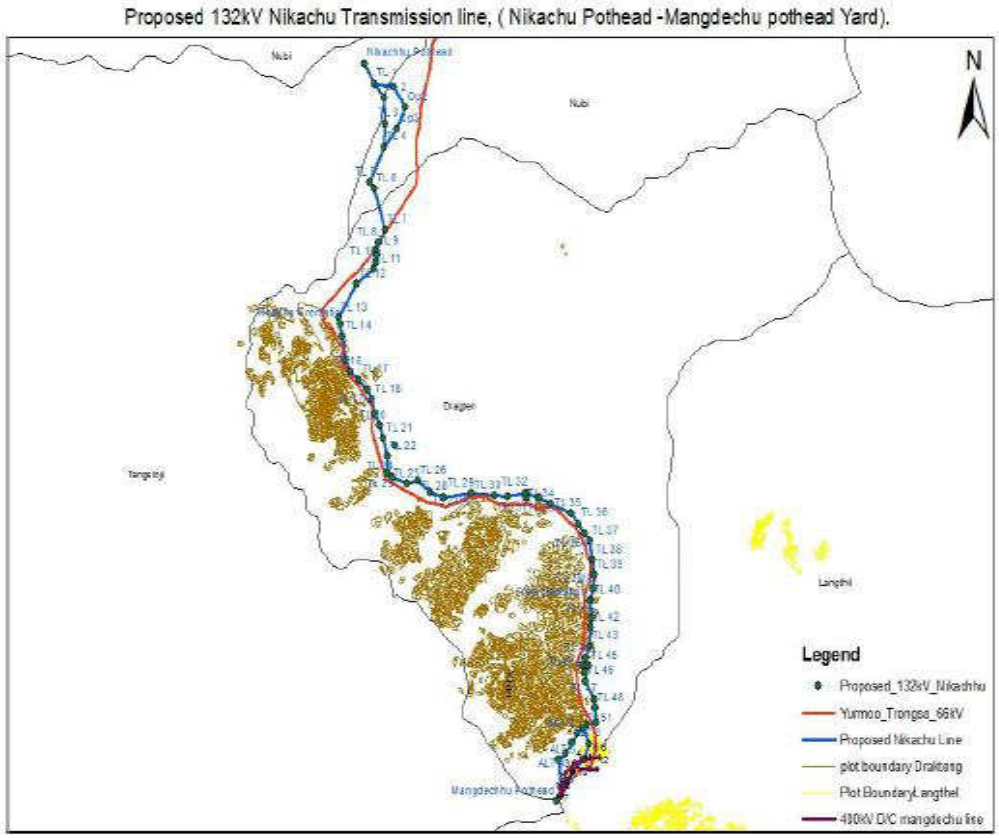


Figure 5-8: Current proposed transmission line alignment (from the BPC walk-through survey, 2013; refinement of Figure 5-7).

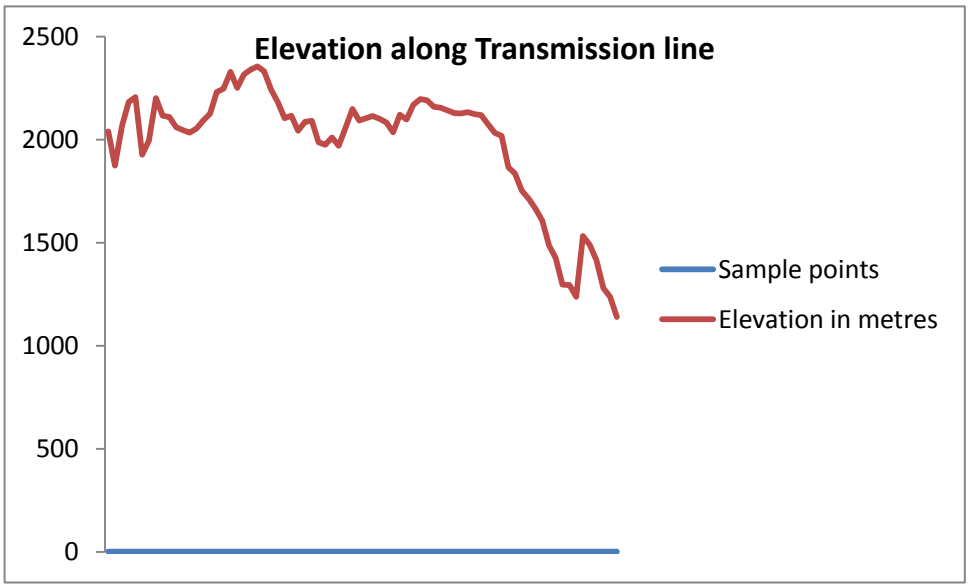


Figure 5-9: Elevation along the proposed transmission line alignment (December 2013).

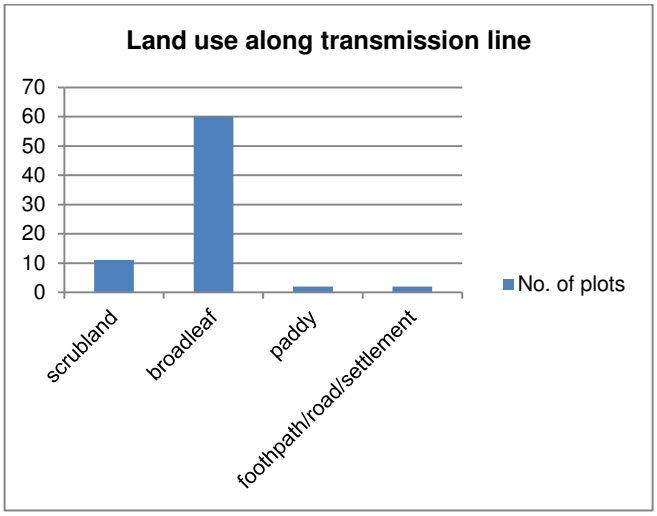


Figure 5-10: Land use along the proposed transmission line.

5.2.6 Climate

The climate data for the project area include temperature, rainfall, and humidity. The nearest meteorological station (run by the Hydro-Met Services Division under the Department of Energy, Ministry of Economic Affairs) to the project site is at Chendebji Village, which is about 6 km from the proposed dam site. The climate data exist for each day of each month over a period of 16 years. Selected data are shown in Figures 5-11 to 5-14 (summer and winter temperatures, maximum monthly rainfall, and maximum and minimum humidity). These serve to show annual variability in the extremes of local climate data. In the period examined, the greatest annual variability was in the rainfall maximums, which reflect a 4x variability (the highest value is 4x greater than the lowest value). Minimum winter temperatures also showed fairly high annual variability, with the warmest minimum winter temperature being 3x higher than the coldest winter minimum temperature.

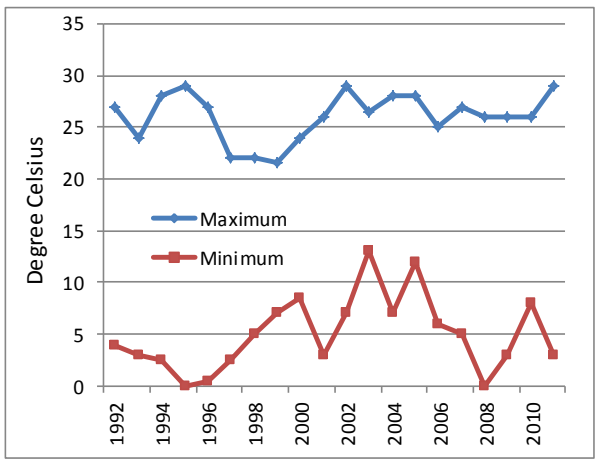


Figure 5-11: Temperature in summer at Chendebji.

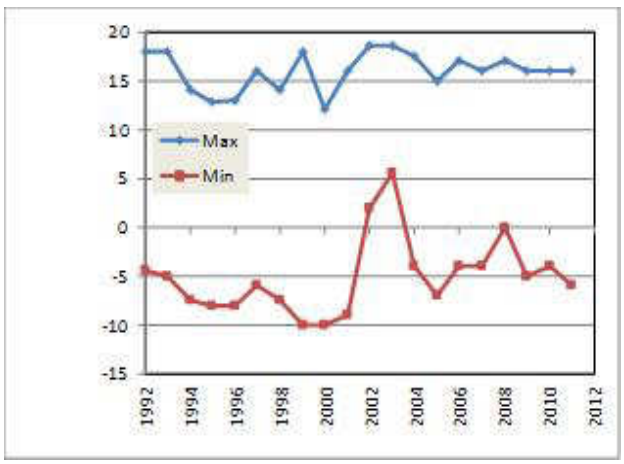


Figure 5-12: Winter temperature, Chendebji.

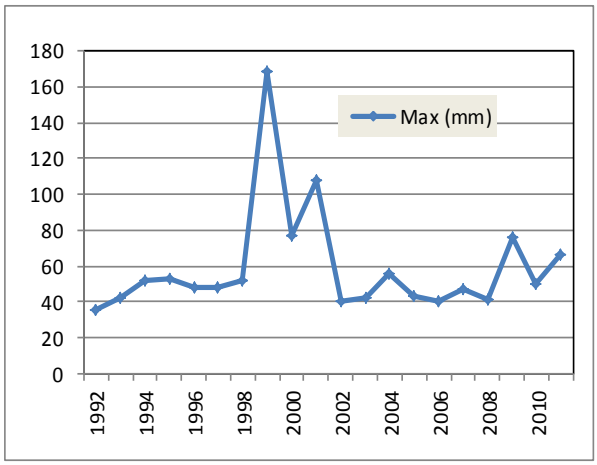


Figure 5-13: Maximum rainfall at Chendebji (mm).

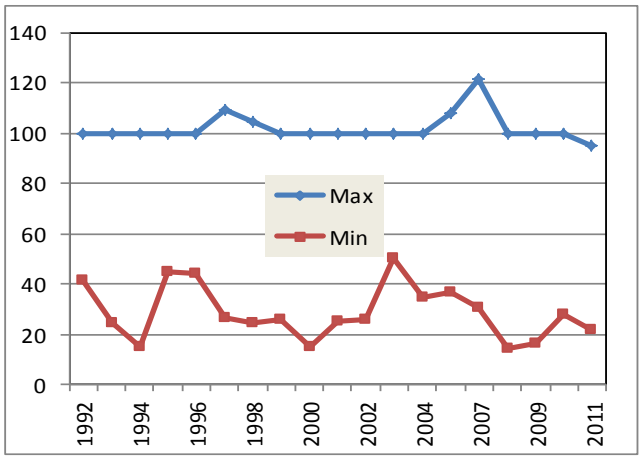


Figure 5-14: Maximum and minimum humidity.

For the project area, the annual climate variation is fairly predictable, with a dry spring starting in early March and running usually to mid-April. Showers usually start about mid-April and continue through the pre-monsoon rains to June. The monsoon last from June to September, characterized by heavy rains, high humidity, misty overcast days, and the risk of flash floods and landslides. Autumn weather is characterized by bright sunny weather running to late November. Winter, from end-November to March, is characterized of course by the lowest temperatures and generally dry weather (except for snow above 3,000 m asl). Average annual rainfall in the project area (based on Chendebji data) is about 1,500 mm/yr (see Figure 5-15). Most of this rain comes between June and September, as noted previously (see Figure 5-16). The monthly variation in rainfall is considerable, with maximum average monthly rainfall in July being more than 21x greater than the minimum average monthly rainfall (in December; see Figure 5-16).

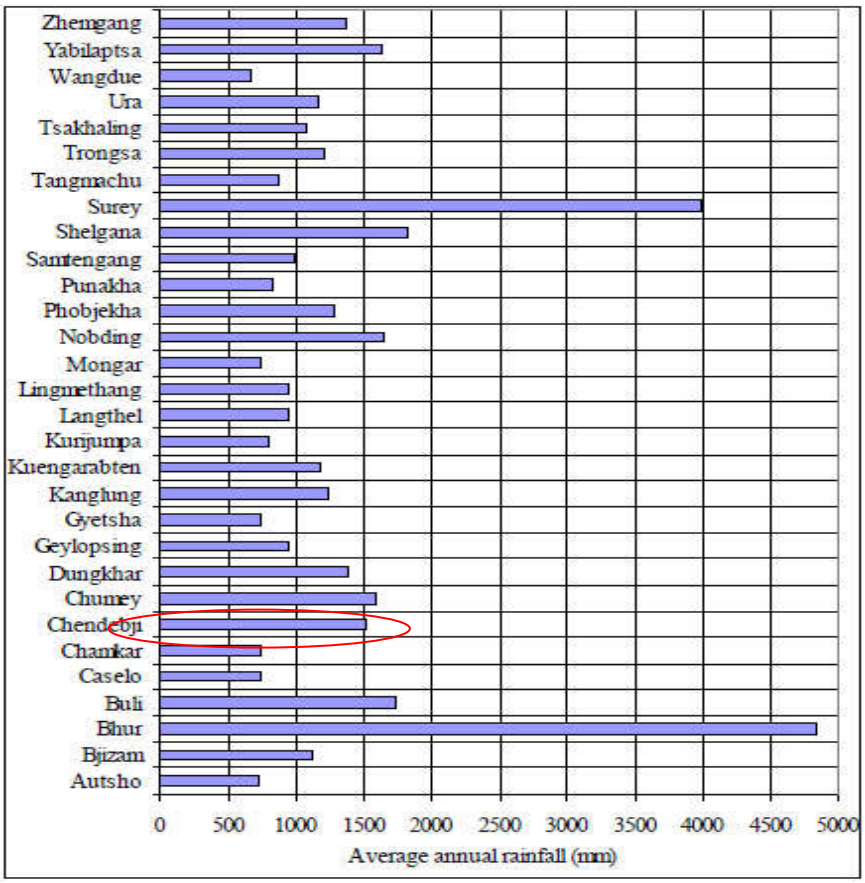


Figure 5-15: Average annual rainfall in Chendebji, compared to other location in and near Trongsa (from the Mangdechhu HPP ESIA).

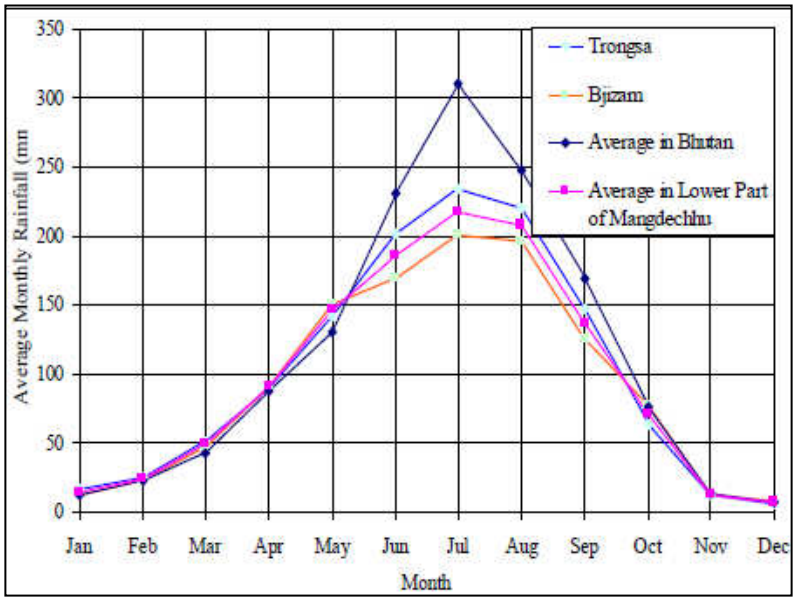


Figure 5-16: Average monthly rainfall in the vicinity of the Nikachhu project site (from the Mangdechhu ESIA).

It is expected that there will little linkage between the Nikachhu project and climate *per se*, except that the variations in weather need to be considered during the construction period. Over the long-term, climate change may be a factor for the hydrological models that support the project design. Climate change is apparent in Bhutan, with anecdotal evidence of increasing temperatures and more untimely and unpredictable rainfall patterns. The recent climate change analysis has clarified these details (see the separate report on this). The mid-century scenarios indicate a possible increase in precipitation over the study area, coupled with an increase in temperatures between 0.5ºC to 2ºC. Higher precipitation and the temperature increase projected under climate change models for the RCP 4.5 scenario are likely to result in increased discharge in the Nikachhu. The projections of average monthly rainfall for the middle of the next century period (2041-60) show a variance across GCMs. Overall, the predicted change in mean annual precipitation from 1986-2005 to 2041-2060 is mostly positive (IPSL-CM5A-MR and MIROC5 predict an increase in rainfall of around 9% and 10.2%, respectively). The projections of temperature for the Nikachhu watershed, based on the global climate models, indicate a likely increase in temperature across the models considered. The minimum temperature for winter months is likely to increase in the range of 0.65°C to 2.4°C across models by 2060, while in summer months the minimum temperature is likely to increase by 0.8°C to 2.5°C by the 2060s. Similarly, the models predict a change in maximum temperatures of approximately +0.7°C to 2.4°C (winter months) and +0.5°C to 2.7°C (summer months).

5.2.7 Nikachhu River Profile and Hydrology

The main feature of the physical environment that the project is most dependent on and which the project, in turn, is likely to impact most significantly (especially during operation) is the hydrology of the Nikachhu, and, less directly, the Nikachhu river profile (this means the elevation changes over distance, including abrupt changes which would be evident as cascades or waterfalls; this has implications for fish migration). The details presented in this section are mainly based on discharge data for the Nikachhu and the Mangdechhu. Calculation of flows was based on catchment area data and flow data recorded at Bjizam (1995-2011), Kurjey (1991-2012) and the Chendebji Gauging Station (2009-2012), and then using deductive analysis for accumulated discharge to isolate the flow specific to the Nikachhu. The detailed hydrological assessment is provided in Annex G. The most salient points, relevant to the environmental and social impact assessment, are presented and discussed below, after an overview of the river systems in Bhutan.

There are four major rivers in Bhutan. The Drangmechhu, the largest river system, flows southwesterly from India's Arunachal Pradesh State, and has three major branches: the Drangmechhu, Mangdechhu, and Chamkharchhu. These branches from the Drangmechhu Basin, which spreads over most of eastern Bhutan and drains the Trongsa and Bumthang valleys. In the southern plains, where eight tributaries join, the Drangmechhu is called the Manas. The Punatsangchhu rises in northwestern Bhutan as the Mochhu and the Phochhu, both fed by the snow-covered Himalayas. These two join to form the Punatsangchhu in Punakha, which flows southerly into West Bengal, India. The smallest river system, the Amochhu flows out of Tibet into the Chumbi Valley, and swiftly through western Bhutan before broadening near Phuentsholing and then flowing into India.

In the project area, the Mangdechhu and Nikachhu dominate. The Mangdechhu flows through the heart of the dzongkhag, dividing the dzongkhag almost in half. The Mangdechhu rises in northern Bhutan near Kula Kangri Peak. At Tongsa Dzong, the bed of the river is about 1,666 m above sea level and its flow is very swift. The Chamkharchhujoins the Mangdechhu,near Gomphu under Zhemgang Dzongkhagbefore it joins the Manas. The Nikachhu is a tributary of the Mangdechhu, with its catchment north and south of the road running from Pele La to Tangsibji. The size of the catchment that “feeds” the Nikachhu (the watershed above the proposed dam at Lorim) measures 373 km^2. There are no glacial lakes in the catchment and therefore the project area is free from the risk of Glacial Lake Outburst Flood (GLOF). The catchment is supplied with snow-melt water and rainfall, most of which is channeled through many smaller tributaries that join the Nikachhu, and most of which discharges in the monsoon (June-September, as noted previously).

The river profile of the Nikachhu is significant for the project. The riverbed drops from about 2,400 masl about 6 km upstream of the proposed dam site to 2,262 m asl at the dam site (at Lorim), and

then to about 1,400 m asl at the confluence with the Mangdechhu, dropping 860 m over about 10 km. There are indications that somewhere between the dam site and the confluence with the Mangdechhu, most likely just after Bangla Pokto (where there is a steep drop in elevation evident in the topographic chart), there is an abrupt drop in the riverbed of about 30 m (a very significant waterfall).[6] Wherever this site is, it was not accessible to the current team; however, there is evidence of waterfalls along the Nikachhu from GoogleEarth images (see Figure 5-17), and an area several kilometers below the proposed dam site has a series of cascades, with heights up to 3.2 m (see Figure 5-18; this is significant for migrating fish, as it is higher than the jumping capability of migratory fish in Bhutan; discussed later in Section 6). The waterfalls are clearly associated with the northwest-southeast traverses that the Nikachhu makes across the prevailing northeast-southwest ridges that connect the mountain systems on either side of the Nikachhu. In this manner, the Nikachhu riverbed drops about 1,000 meters over 12-13 km.

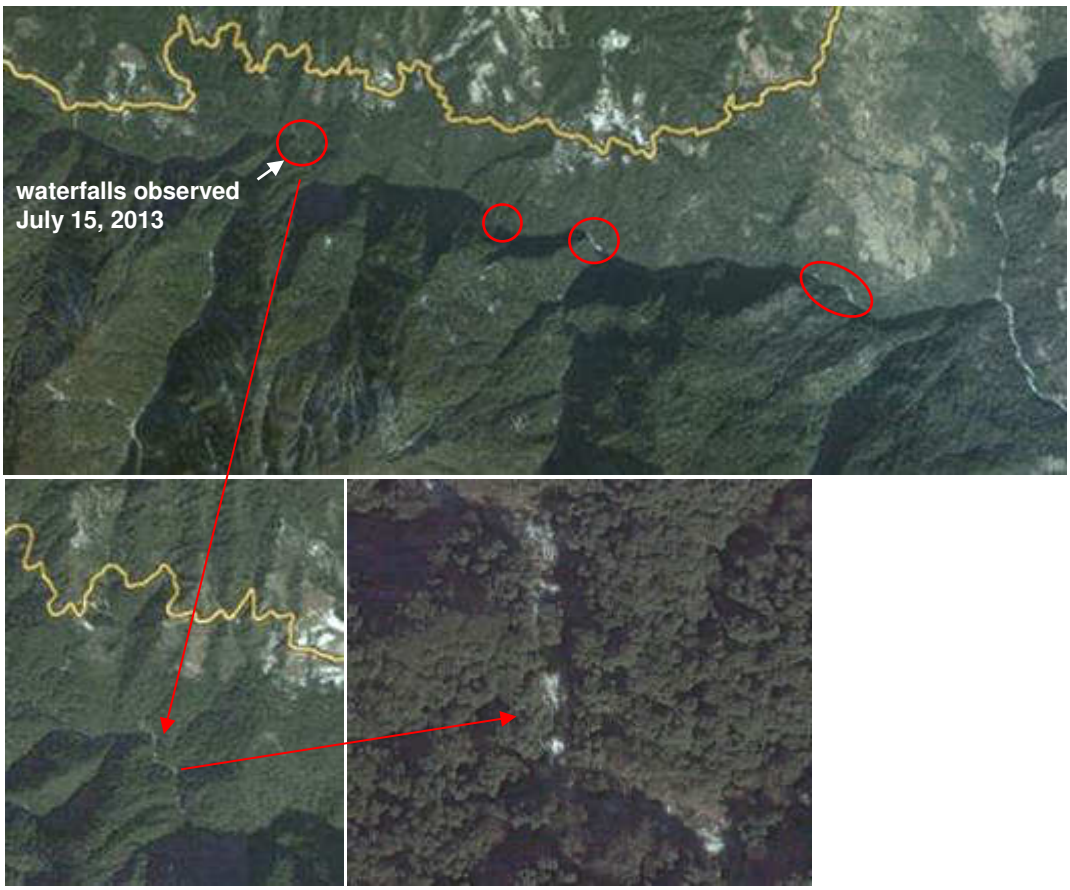


Figure 5-17: Locations of waterfalls on the Nikachhu, downstream from the proposed dam site.

[6] Recorded by a BHUCORE consultant in July 2010, and also noted by local people and the previous fishing warden, Mr. Phuntsho.

Figure 5-18: Waterfalls and rapids in the Nikachhu.

The mean monthly discharges at the Bjizam andNikachhu dam site are shown in Table 5-3.

Table 5-3: The average monthly flow derived from long term flow series (1991-2012) at Bjizam and Dam site of Nikachhu.

Month	Bjizam Flow m^3/s	Nikachhu Flow m^3/s
Jan	15.79	5.11
Feb	14.57	4.84
Mar	17.80	5.51
Apr	29.99	7.90
May	53.55	13.00
Jun	94.81	22.27
Jul	164.90	37.86
Aug	164.80	39.74
Sep	118.12	29.27

Month	Bjizam Flow m^3/s	Nikachhu Flow m^3/s
Oct	59.95	15.37
Nov	30.04	8.42
Dec	20.04	6.01
Average flow	**65.36**	**16.27**
Minimum flow	**14.57**	**4.84**
Maximum flow	**164.90**	**39.74**
Average lean flow (Dec-March)	**17.05**	**5.37**

At the Nikachhu Dam site, it is seen that minimum flow is 4.84 m^3/s and average lean flow (Dec-Mar) is 5.37 m^3/s. The average flow is 16.27 m^3/s and the maximum flow is 39.74 m^3/s.

The catchment area of the Mangdechhu at the dam site is 1,506 km^2. The maximum design discharge of Nikachhu with 10% overloading is 28 m^3/s. The combined mean monthly flow of Nikachhu and Mangdechhu at the Mangdechhu dam site is shown in Table 5-4.

Table 5-4: Mean monthly flows at Nikachhu and Mangdechhu Dam Site.

Months	Mangdechhu (m^3/s)	Nikachhu (m^3/s)	Combined flow at Mangdechhu dam site (m^3/s)
Jan	17.6	5.11	22.16
Feb	16.72	4.84	21.01
March	20.13	5.51	25.09
April	32	7.90	39.35
May	58.02	13.00	70.47
June	103.71	22.27	125.43
July	174.61	37.86	202.38
Aug	185.77	39.74	213.55
Sept	131.23	29.27	159.01
Oct	63.91	15.37	78.73
Nov	32.43	8.42	40.30

Months	Mangdechhu (m^3/s)	Nikachhu (m^3/s)	Combined flow at Mangdechhu dam site (m^3/s)
Dec	21.83	6.01	27.29

The climate change risk analysis (noted previously) suggests that the mean annual flow available for hydropower production from 1986-2005 to 2041-2060 is estimated to remain more or less the same, showing a slight increase varying between 3% - 5% for the considered climate model. The flow duration curves show a slight increase in peak flows by 5% - 8% and variability in lean flows (1% - 3%). However, these flow changes are not likely to impact the hydropower operations adversely.

5.2.8 Sedimentation Data for Nikachhu

The review of sediment data shows that the largest silt concentration observed over September 2009 to July 2013 is 9,212.71 ppm, observed on 16th February 2010. This value is exceptionally high. The next largest silt concentration measured at the site is 6,690.51 ppm, observed on 14th September 2012. The sediment particles vary between 2,000 microns and 0.24 microns (µ) in size. While the mean size of the sediments collected at the dam site is 610.9 µ, the median size is 533.6 µ. The mineralogical composition suggests that presence of quartz particles varies between 47% (for a grain size of 0.5-1.18 mm) and 76% (for particles less than 90 µ in size). For very large particles greater than 1.18 mm in size, the fraction of quartz is 14%. Feldspar constitutes the next predominant mineral type, being 47% for particles greater than 1.18 mm in size that gradually reduces to 8% for particles finer than 90 micron. These hard minerals are harmful as they wear away the electromechanical components in contact with water. Therefore, De-silting Chambers have been included in the design for exclusion of sediments as a special provision.

Sedimentation data in the Nikachhu from the year 2009 to 2013 is appended as **Annex-F**.

5.2.9 Air Quality

Air quality could possibly be affected in a transient manner during construction, especially near construction equipment. It is, however, a fairly conservative physical parameter that is not much affected by development, especially in this part of Bhutan, where population density is quite low and there is little traffic and almost no industry. Air sampling was done using a Respirable Dust Sampler Environtech APM 460DBL at two locations: one at the house near the dam site; and, and the other at the Trongsa View Hotel. This equipment measures particles less than 10 microns (commonly referred to as PM10), and allows for analysis of SO_x (sulphur oxides) and nitrous oxides (NO_x). The existing air quality at the project site was determined by carrying out ambient air quality

sampling at the two locations on July 31, 2012 for 24 hours. The sampling coordinates and results are shown in Table 5-5.

Table 5-5: Air sampling stations, coordinates, and results.

Location name	Northing	Easting	Particulate Matter (PM10)	SO_x	NO_x
Lorim	27°27'5.86"N	90°22'22.57" E	20.293 µg/m^3	BDL*	BDL
Trongsa View Hotel	27°29'40.92" N	90°29'31.33" E	24.607 µg/m^3	BDL	BDL
Bhutan standard for sensitive areas			**75 µg/m^3**	**30 µg/m^3**	**30 µg/m^3**
WHO/World Bank guideline			150 µg/m^3	125 µg/m^3 24-hr average	40 µg/m^3 yearly average

** BDL: below detection limit.*

Sulphur oxides and nitrous oxides were not detected while analyzing (reflecting the low population density, absence of heavy industry, and low traffic levels). These results were substantiated by the air sampling results from nineteen of twenty sites at the Mangdechhu Hydropower Project sites, where SO_x and NO_x were also below detection limits. Particulate matter (PM10) in the Nikachhu project area was quite consistent at 20.3 - 24.6 µg/m^3, only about one-third of the standard for Bhutan (similar to the Mangdechhu area); see Table 5-6. Given the situation in the Nikachhu project area, with the majority of the district electrified, the only real sources of air contaminants are the small amount of traffic and a number of rural households where wood and kerosene are the main fuel for cooking and heating. The latter may result in localized increases in levels of smoke and soot (contributing to PM10), and carbon dioxide, when fuel usage is highest (in the evening and during the winter).

Table 5-6: Ambient air quality standards (maximum permissible limits in µg/m^3); NECS Bhutan.

Parameter	Industrial Area	Mixed Area	Sensitive Area
Total Suspended Particulate Matter			

Parameter	Industrial Area	Mixed Area	Sensitive Area
24 Hour Average	500	200	100
Yearly Average	360	140	70
Respirable Particulate Matter (PM10)			
24 Hour Average	200	100	**75**
Yearly Average	120	60	50
Sulfur Dioxide			
24 Hour Average	120	80	**30**
Yearly Average	80	60	15
Nitrogen Oxides			
24 Hour Average	120	80	**30**
Yearly Average	80	60	15
Carbon Monoxide			
8 Hour Average	5,000	2,000	1,000
1 hour Average	10,000	4,000	2,000

5.2.10 Noise

Noise was measured using a sound level meter (SLM 100; manufactured by Envirotech Instruments Pvt. Ltd, New Delhi). Noise was monitored at the same locations as the air quality measurements, over a 24-hour period to reflect day and night noise levels. The baseline data are shown in Table 5-7. The data indicate that noise levels are currently below the national standards for noise, day and night. Not surprisingly, noise levels are higher in town, compared to the proposed dam site.

Table 5-7: Baseline noise levels (sampled July 2012); all well below Bhutan and WHO/World Bank guidelines.

National Standard		Trongsa View Hotel		Dam Site	
		27°29'40.92"N; 90°29'31.33"E		27°27'5.86"N ; 90°22'22.57"E	
Day	Night	Day	Night	Day	Night
55 dB(A)	45 dB(A)	48.11 dB(A)	42.84 dB(A)	40.7 dB(A)	35.49 dB(A)

5.2.11 Surface Water

Water quality was tested with *in situ* and laboratory analysis (in the July field program). The *in situ* tests were carried out using the following equipment: a turbidity tube, and a water testing kit (Hach series HQ40d, with three probes to measure LDO, pH, temperature, conductivity, and chlorine). The arsenic and coliform tests were done in the field but also in the temporary laboratory. The micro-biological test was conducted within six hours of collection of the sample. An EZ Arsenic Kit 2822800 was used for the arsenic test, while the Oxfam DelAgua Water Testing Kit with a single incubator was used for the coliform analysis. Water quality tests were carried out at four sites: one immediately above the proposed dam site; downstream from the Nikachhu dam site; after the confluence of the Nikachhu and the Mangdechhu; and, the fourth at Tsheringma Drupchhu. The sampling site coordinates are shown in Table 5-8. Water quality was examined again in December 2012, along the Nikachhu and at several locations on the Mangdechhu. The surface water quality analytical results are shown in Tables 5-9 and 5-10.

Table 5-8: Coordinates of the water sampling sites.

Sample Site Description	Northing	Easting
Upstream of Nikachhu Dam Site	27°27'11.92"	90°21'59.99"
Downstream of Nikachhu Dam Site	27°25'55.10"	90°7'2.64"
Downstream of Nikachhu and Mangdechhu Confluence	27°22'11.17"	90°1'59.62"
Tsheringma Drupchhu	27°27'02.90"	90°26'36.6"

Table 5-9a: Water quality at the project site and downstream (sampled July 24-29, 2012).

Parameter	Unit	Category	Locations		
			Upstream of Nikachhu Dam Site	Downstream of Nikachhu Dam Site	Downstream of Nikachhu and Mangdechhu Confluence
Turbidity	TU	Physical	17	18	22
pH		Physical	7.52	7.4	7.6
Temperature	centigrade	Physical	13.4	16.5	16.2
Conductivity	µg/L	Physical	62.8	58.5	51.1
Dissolved Oxygen	mg/L	Physical	7.91	8.49	9.3
Coliform	cfu/ml	Microbiological	25	29	70
Chlorine	mg/L	Chemical	< 0.05	< 0.05	< 0.05

Parameter	Unit	Category	Locations		
			Upstream of Nikachhu Dam Site	Downstream of Nikachhu Dam Site	Downstream of Nikachhu and Mangdechhu Confluence
Arsenic 50 ml	Ppb	Chemical	0	0	0
Arsenic 9.6 ml	Ppb	Chemical	0	0	0
Iron	mg/L	Chemical	0.082	0.065	0.82
Ammonia	mg/L	Chemical	0.025	0.025	0.016
Total Hardness	mg/L	Chemical	80	81	86
Calcium	mg/L	Chemical	59	45	19
Magnesium	mg/L	Chemical	21	27	67

Table 5-9b: Water quality at the project site and downstream (sampled December, 2012).

Parameters	Sites					
	Near dam site	Downstream from Dam Site	Confluence with Mangdechhu	Downstream from Confluence	Downstream Mangdechhu	Downstream Mangdechhu
Conductivity (µm/s)	82	82	117	90	105	110
TDS (ppm)	41	41	57	44	52	56
Water Temp. (^{o}C)	7	7	9	9	10.5	12

Table 5-10: Water quality at Tsheringma Drupchhu (July 2012).

Parameter	Unit	Measurement at Tsheringma Drupchhu
Turbidity	TU	8
pH		6.8
Temperature	Centigrade	13.8
Conductivity	µS/cm	29.7
Dissolved Oxygen	mg/L	7.69
Chlorine	mg/L	0
Arsenic (50 ml)	Ppb	0

Parameter	Unit	Measurement at Tsheringma Drupchhu
Arsenic (9.6 ml)	Ppb	0
Coliform	cfu/ml	71

There is little variation in water quality parameters above and below the proposed dam site on the Nikachhu, with the exception that the downstream water has higher levels of dissolved oxygen, which probably reflects the high turbulence as the Nikachhu steepens its descent to the Mangdechhu. In general, the analytical data for the Nikachhu reflect a very healthy river system, with no evidence of contamination from human sources. In addition, despite water sampling at the beginning of the monsoon, turbidity is actually very low, reflecting very little sediment mobilization (from erosion) in the upper watershed of the Nikachhu (which in turn reflects very high vegetative cover).

On the other hand, there is some evidence of higher levels of some water quality parameters in the Mangdechhu below the confluence. Given the much higher discharge of the Mangdechhu and the fact that it flows near Trongsa town, it is not surprising that there are higher levels of coliform. The surficial geology of the Mangdechhu Basin may also account for the higher levels of iron and magnesium, and lower levels of calcium. Like the Nikachhu, the Mangdechhu shows little evidence of contamination from human activity, and all parameters, such as turbidity, ammonia, and coliform are low by any standard. Water quality at Tsheringma Drupchhu (a small tributary of the Nikachhu, on the north side, about 2 km upstream of the confluence of the Nikachhu and Mangdechhu) is also very good, although coliform levels are similar to those in the Mangdechhu (possibly reflecting more human habitation and pastureland in this area, compared to further upstream on the Nikachhu).

The water quality analysis in December, of course, reflected lower water temperatures, but showed the trend of increasing water temperatures from the Nikachhu to the Mangdechhu (the latter at lower altitudes). As with the July data, the Mangdechhu showed higher levels of total dissolved solids and conductivity, compared to the Nikachhu.

5.2.12 Groundwater

Little is known of Bhutan's groundwater reserves, although there are many springs in both low and high altitudes, some of which are used for irrigation and/or domestic purposes. There has been no significant study on the location, extent and potential yield of aquifers, or on the quality of the water they contain. Arsenic levels are, however, known to be low, and water quality should be good, given the limited population, lack of polluting industries, and relatively low use of chemical fertilizers in agriculture in the project area. It is known that no local communities use wells for any water supply.

5.3 Biological Features

5.3.1 Introduction

Bhutan ranks in the top 10% of the countries in the world with the highest species density (species richness per unit area). It also has the highest ratio of land that is in protected status, and has the highest portion of forest cover of all countries in Asia (Biodiversity Action Plan (BAP) for Bhutan, 2002). For the baseline assessment, it is important to document the presence of important and vulnerable habitats and species in the possible zone of influence of the project area, but to avoid description of the whole suite of diversity and species that will not likely be affected by the project, in order to maintain a focus on required mitigation measures and residual impacts (this reflects the concept of valued ecosystem components; those which are important and vulnerable, rather than describing everything). This section on biological features is therefore organized to mainly describe vulnerable features related to the National Park (Jigme Singye Wangchuck National Park), the biological corridor that the project will have some influence on, vegetative cover and habitats (flora), wildlife (including birds), and fish (fauna). Other biological features are described, when necessary, if they are perceived to be vulnerable to certain aspects of the project. Annexes 2 and 3 provide details on the terrestrial and aquatic surveys (two of each, in different seasons) which inform this section.

5.3.2 The National Park and Biological Corridor

5.3.2.1 Biodiversity Context

As noted above, Bhutan has the highest proportion of forest cover and protected areas compared to all other countries in Asia[7]. With a total land area of 38,394 km^2, protected areas cover 51.32% (19,676.57 km^2). This comprises 16,396.43 km^2 in ten protected areas and 3,307.14 km^2 of Biological Corridors (Circular of NCD, Nov 30, 2009; NEC/Adm(02)/2009/1595). These are shown in Figure 5-19. The project area is on the edge of the Jigme Singye Wangchuck National Park (JSWNP; just the edge of the buffer zone, in about 10-20 m, for a distance of about 700 m), and will temporarily take up a very small percentage (12-15% of the width) of the eastern biological corridor that joins JSWNP and Wangchuck Centennial Park (this corridor is presently crossed by the National Highway, in any case).

[7] MOA (2002): Biodiversity Action Plan for Bhutan. Ministry of Agriculture, RGOB.

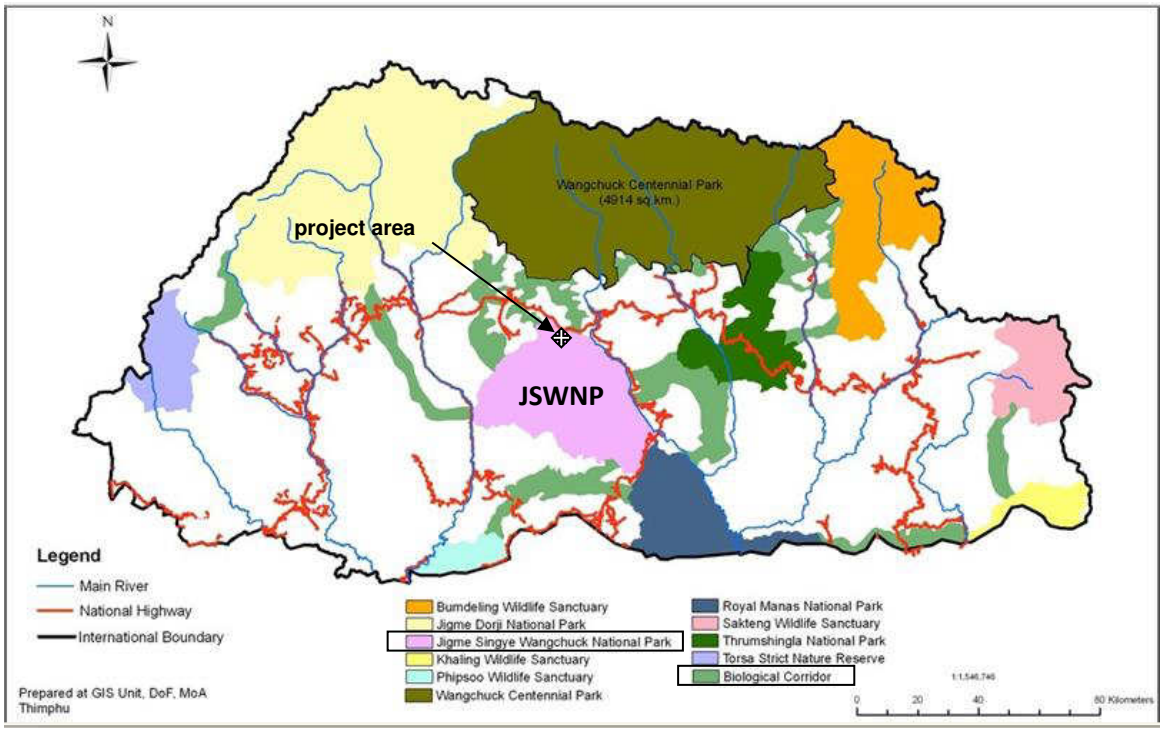


Figure 5-19: National parks and biological corridors in Bhutan (the project area is marked).

The protected areas in Bhutan are all joined by biological corridors, which are intended to maintain the biological connection between each area, and permit the unhindered migration of mammals and other organisms. As noted previously, these are all considered as protected areas by the Department of Forest and are given special protection under the Forest and Nature Conservation Act (1995), although with a lower status than the National Parks themselves.

To date around 5,603 species of vascular plants, over 678 species of birds, and nearly 200 species of mammals have been recorded in Bhutan (BAP, 2009). This possibly represents a fraction of the species that are present, as Bhutan remains one of the least explored countries in the world. The rich biodiversity is due to the remote nature, geographical relief and climatic heterogeneity of the country, and its location between temperate Eurasia in the north and the tropical Indian subcontinent in the south. The National Parks are intended to protect the most important habitats for this terrestrial biodiversity.

5.3.2.2 Jigme Singye Wangchuck National Park (JSWNP)

The Jigme Singye Wangchuck National Park (JSWNP) was established in 1995, and covers an area of 1,723 km^2. The Park falls within five districts, including Trongsa (the other dzongkhags are Zhemgang, Wangdue Phodrang, Tsirang, and Sarpang); see Figure 5-19. In Trongsa district, the Park spreads over almost three geogs (Khorphu, Langthil, and Tangsibji). The Park headquarters are located at Tshangkha (see Figure 5-20). Over 5,000 species of vascular plants are expected in JSWNP; a total of 38 different mammal species and 270 species of birds have been recorded in the

Park, either by direct sighting or indirect evidence. There are currently about 6,000 park residents in 31 villages within park boundaries, and apparently another 15,000 within the "buffer" (the 1-5 km wide zone on the periphery of the park, within the park boundary). There is a very high diversity of habitats, so plants and animals that occur in one part of this large park may not exist in other parts; uniform animal and plant distribution therefore cannot be assumed. In fact, the only part of the park that will be influenced by the project is a thin steep-slope wedge near Lorim that will be inundated behind the diversion dam. The slope in this area is too steep to support large animal access to the Nikachhu.

Regarding the concept of buffer zones, this has changed in the last ten years (and is apparently still in evolution, based on recent variable interpretations of the Park buffer zone). Before 2004, a buffer zone meant areas outside of the National Park boundary (usually, a width of 5 km). However, the concept was changed by the Department of Forests in 2004, to accommodate the concept of a National Park boundary being demarcated by physical features (such as steep mountain slopes or rivers that act as barriers). With this concept, all buffer zones are *included* within the National Park boundary. Hence, the Forest and Nature Conservation Rules, 2006 describe a "Buffer Zone" as an area set aside as a cushion *within* the Protected Area boundary.[8] JSWNP currently accepts the buffer zone as "a distance of 1-5 km width, depending on the topography from the Protected Area boundary". Buffer zones are intended to allow some controlled development (in fact, quite a few types of activities) adjacent to and within the peripheries of National Parks (see Table 5-11).

For the purpose of administration and management of JSWNP, the Park's jurisdiction is just within the boundary. In this part of JSWNP, the boundary is the right bank of the Nikachhu, stretching from Chendebji village to the confluence with the Mangdechhu. As such, with the current concept of the buffer zone (at least one kilometer wide, *inside* the park boundary) the project "footprint" during construction and operation will clearly occur within this buffer zone (encroachment will probably be less than 20 meters). On the basis of this small project "footprint" within the buffer, rather than in the National Park, clearance has been issued for project activity at the boundary of JSWNP.

[8] pers. com., Kelzang Wangchuk, Park Manager, JSWNP, Tshankha.

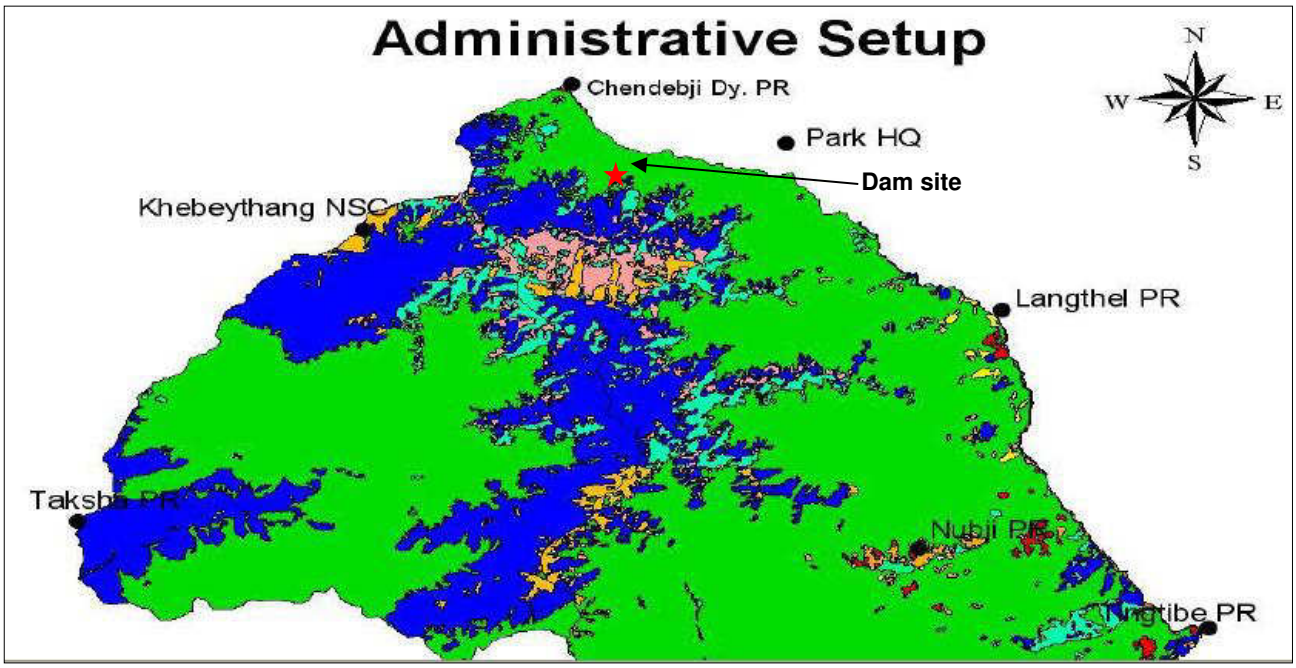


Figure 5-20: JSWNP in the vicinity of the proposed Nikachhu project.

Table 5-11: Classification of activities within buffer zones; activities allowed (✓) or prohibited (×) in different zones (source: BWS Conservation Management Plan, 2001; Royal Government of Bhutan).

Activity	Core Zone and Low Impact Trail	Multiple Use Zone and Normal Trails	Buffer Zone	Remarks
Roads	×	×	×/✓Restricted in Gov. Forest	Requires EIA
Industry	×	✓Cottage industry	×/✓ (some)	Requires EIA
House construction, settlement	×	✓ *	×/✓	* No new settlements and no in-migration
Cultivation	×	✓	✓	On registered land
Grazing	× Except in very special cases	✓	✓ (some) Can be regulated in Gov. Forest	On registered tsamdrog only; Grazing may not violate the management plan

Activity	Core Zone and Low Impact Trail	Multiple Use Zone and Normal Trails	Buffer Zone	Remarks
Pasture improvement	×	✓	✓	In registered pasture land and only non-aggressive species
Fuelwood, construction wood	×	✓	✓	Requires marking by park rangers /park guards / territorial staff, Along trails only fallen trees or those cut for maintenance
Forest produce, incl. dry wood, soil, stones, fodder, fruits, vegetables, mushrooms, leaf litter, etc.	×	✓	✓	For personal use or cottage industry, Commercial use requires permit
Social/community forestry	×	✓	×/✓ (some)	Specifically in degraded areas
Logging	×	×	×/✓ (some)	FMU's require EIA and involvement of sanctuary management
Camping	×	✓	×/✓	
Visitors, migrating herds	×, Except for passage*	✓	✓	*No stops for grazing, collecting forest products, etc.
Research	✓	✓	✓	Only research contemplated in the management plan, or sanctioned by sanctuary management.
Habitat management, pest control	(×) In principle not	✓	✓	If research indicates necessity, or to mitigate effects of natural hazards, such as fires and pests

Activity	Core Zone and Low Impact Trail	Multiple Use Zone and Normal Trails	Buffer Zone	Remarks
Hunting, fishing	×	✓	×/✓	Of non-protected species and only with permit

5.3.2.3 The Biological Corridor

As noted previously, there are three biological corridors that connect JSWNP to the Wangchuck Centennial Park in the north of Bhutan. One of the adits and muck disposal areas for the project will occur within the eastern-most corridor. Biological corridors are areas set aside to connect one or more protected areas, which are conserved and managed for the safe movement of wildlife. Biological corridors do not have the same legal status as a National Park, a Wildlife Sanctuary, or a Strict Nature Reserve, but development activities, such as construction of motor roads, transmission lines, buildings, fences or any physical structures, require a permit from the DoF. However, the concept of biological corridors is to enable, rather than constrain. For example, the DoF indicates the following: "Roads and most human uses will be prohibited in core zones. However, an outright prohibition on roads (or hydroelectric project, or other human uses) in the corridor would be at odds with Bhutan's legitimate policies to expand the nation's infrastructure. Therefore, Sections 3.3 through 3.8 try to harmonize mandates by setting out guidelines that will allow such activities to proceed with minimal impact to wildlife movement. In this way, each Corridor Management Plan can emphasize enabling over constraining". With the three corridors connecting JSWNP to protected areas in the north, the actual protected linkage is about 13-14 km wide (when all three are combined), which gives some scope for the allowed restricted activities within biological corridors (and the eastern corridor, which is about 5 km wide, is already completely crossed by the National Highway). Table 5-12 shows the relative importance of the eastern biological corridor connecting JSWNP and Wangchuck Centennial Park.

Table 5-12: Relative importance of the JSWNP-WCP biological corridors (from Biological Corridors Regulation, Bhutan).

Biological Corridor[a]	Wildlife species of interest (MacKinnon 1999)	Area (km²)	Length (km)	Bottle-necks < 1 km wide	Households in Corridor		Households in 500 m buffer		Geogs	Dzongkhags	Territorial Divisions	FMUs (as of 2005)
					N	N/ km²	N	N/km²[b]				
1. TSNR to JDWNP	Takin, blue sheep, musk deer, red panda, snow leopard	149	30	0	40	0.3	239	8.0	Tsento, Biji	Haa, Paro	Paro	None
2. JDWNP to JSWNP	Red panda, musk deer	275	56	2	275	1.0	492	8.8	Kabjisa, Toepisa, Chang, Nahi, GaseWom, Daga	Punakha, Thimphu, Wangdue	Wangdue, Thimphu	Chamgang – Helela
3. Phipsoo WS to JSWNP & RMNP	Tiger, gaur, elephant	376	51	2	311	0.8	1336	26.2	Dungjegang, Beteni, Senge, Hile, Dobhan, Leopani, Bhur, Surey, Serzhong, Dhanaban	Sarpang, Tsirang	Tsirang, Sarpang	None
4. Thrumshingla to RMNP and JSWNP	Tiger	501	40	2	63	0.1	489	12.2	Chumey, Langthel, Nangkhor, Trong, Shingkhar	Trongsa, Zhemgang, Bumthang	Bumthang, Zhemgang	Kikhar Buli
5. RMNP to Khaling WS	Tiger, gaur, elephant, rhino	212	49	3	95	0.4	456	9.3	Norbugang, Bakuli, Orong	Samdrup-Jongkhar	Samdrup-Jongkhar	None
6. Khaling WS to Sakteng WS	Tiger, gaur	160	32	0	1	0.0	1	0.0	Serthi, Shingkarlauri, Kangpara, Martsala, Samrang	Trashigang, Samdrup-Jongkhar	Trashigang, Samdrup-Jongkhar	None
7. Thrumshingla NP to Bomdeling WS	Tiger, red panda, musk deer	79	17	1	188	2.4	327	19.2	Jare, Tsamang, Tsengkhar, Shermuing	Mongar, Lhuentse	Mongar	None
8. JSWNP to WCNP & JDWNP	Tiger, takin, blue sheep, red panda, musk deer	601	55	2	N/A	N/A	N/A	N/A	N/A	Wangdue, Trongsa	Wangdue, Bumthang	Three FMUs
9. WCNP to Bomdeling WS	N/A	119	17	3	N/A	N/A	N/A	N/A	N/A	Lhuentse	Mongar	None
Total		2472		15	973		3340		> 35	12	10	8

[a] Abbreviations: JDW = Jigme Digye Wangchuck, JSW = Jigme Singye Wangchuck, NP = National Park, RM = Royal Manas, SNR= Strict Nature Reserve, WC = Wangchuck Centennial, WS = Wildlife Sanctuary.
[b] Household density in buffer zone = households/corridor length (= household per km² because the combined buffers are 1 km wide).

8. JSWNP to WCNP & JDWNP | Tiger, takin, blue sheep, red panda, musk deer | 601 | 55 | 2 | N/A | N/A | N/A | N/A | N/A | Wangdue, Trongsa | Wangdue, Bumthang | Three FMUs

The three corridors that connect JSWNP and Wangchuck Centennial National Park (WCNP) combined represent the largest area (601 km^2) compared to all the other biological corridors. The species of interest that may be using these corridors include: tiger; takin; blue sheep; red panda; and musk deer (see Table 5-14); recent site visits indicated that scat of protected animals are evident in the eastern corridor (where Adit 2 will be located). Tigers have been associated with five other corridors, so are not restricted to just the JSWNP-WCNP corridors. Takins and blue sheep are associated with one other corridor (TSNR-JDWNP), and red pandas are associated with two other corridors; musk deer with three other biological corridors (Table 5-14). The main point here is that the JSWNP-WCNP corridors, especially the eastern one (of three) are not unique in providing safe movement corridors for the species of interest; animals will still be able to move within this

corridor, around construction activity, given the width of the corridor, and also will have options to move in other corridors (this is discussed further below).

5.3.3 Vegetative Cover and Habitats

5.3.3.1 Overview of Forest Types and Associated Ground Cover

Lying between the cold and dry Tibetan plateau in the north and the hot and humid Indian plains in the south, Bhutan straddles two major biogeographic realms. These are the IndoMalayan region consisting of the lowland rain forests of South and Southeast Asia and the Palearctic region, consisting of conifer forests and alpine meadows of northern Asia and Europe (BAP, 2009). Forests cover 72.5% of the country's land cover. Due to the great range in altitudes from south to north, as well as the corresponding variation in climatic conditions, from hot and humid sub-tropical conditions in the southern foothills to cold and dry tundric conditions in the northern mountains, the country is characterized by a wide range of forest ecosystems and vegetation zones. Broadly speaking, there are three distinct eco-floristic zones:

- the alpine zone above 4,000 m, where there is no tree cover; just scrub vegetation and meadows;
- the temperate zone between 2,000 m and 4,000 m, containing temperate conifer and broadleaf forests (this is the altitude zone of the project, at about 2,200 – 2,700 m asl); and,
- the subtropical zone, between 150 m and 2,000 m, containing tropical and subtropical vegetation.

Within the spectrum of the above three broad eco-floristic zones, a number of forest types occur, which include: Alpine Meadows and Scrub; Fir Forest; Mixed Conifer Forest; Blue Pine Forest; Chir Pine Forest; Broadleaf mixed with Conifer Forest; Upland Hardwood Forest; Lowland Hardwood Forest; and, Tropical Lowland Forest.

Within Trongsa Dzongkhag, the majority of the project area falls in the Government Reserve Forest. Forest covers 87.6% of the total land area, a significant degree of coverage. Within the Dzongkhag, the overall distribution of forest types is as follows:

- Broadleaf forest (40.5%): these forests are mostly characterized by trees such as *Alnus nepalensis* (alder);
- Mixed conifer (15.1%): prevalent between 2,000 m and 2,700 m, this forest type is dominated by spruce, hemlock and larch, or a mixture of these species;
- Broad leaf and conifer (11.4%): these mixed forests are generally oak mixed with blue pine, or higher altitude broadleaf species mixed with spruce or hemlock, and generally occur between 2,400 m and 3,000 m;

- Scrub forest (9.9%): this is generally forest that has been either de-forested, damaged by fire, or overgrazed, and is more dominated by scrub than trees;
- Fir forests (8.8%): this forest type occurs at very high altitudes, between 2,700 m and 3,800 m; hemlock and birch may also be present; towards the timber line, fir stands become stunted, and juniper and rhododendron scrubs become more prominent;
- Chirpine (1.3%): a xerophytic forest type occurring in deep dry valleys under subtropical conditions, between 900 m and 1,800 m;
- Blue pine (0.5%): most common in valleys between 1,800 m and 3,000 m; it is sometime found mixed with oak and rhododendron.

As the project area lies within altitudes of about 2,200 m and 2,700 m, the forest type is typically cool broadleaved forest, mixed with conifers, or temperate forest (see also Figure 5-6 for the distribution of broadleaf forest in the district). The typical structure of these forests includes the following layers: a top canopy comprising tall mature trees; a shade-tolerant middle canopy comprising smaller mature trees; shrub layer, comprising mostly woody or herbaceous plants; followed by the ground cover. The dominant trees include the evergreen Oaks (*Quercus glauca*, *Quercus serrata*, *Quercus lanata*), mixed with Birches (*Betula* spp.), Maples (*Acer* spp.), and evergreens, such as *Castanopsis* and *Persea*, as well as some magnolias. Some of the coniferous trees, such as Pines (*Pinus* spp.) and Spruce (*Picea* spp.) are found here as well. Maple and *Castonopsis* spp. predominate at lower altitudes, while oak predominates higher up; alders are also common; *Carpinus veminii* (ash) is also evident throughout the top canopy. With increasing altitude, these forests grade towards blue pine with xerophytic oaks. *Quercus griffithii*, a deciduous oak thrives in the vicinity of Tangsibji and Tshangkha, mainly protected by the individual households, until recent times, for leaf collection for cattle bedding and branches for mushroom cultivation. None of the top canopy trees observed in the project area are endangered, protected, or endemic.

The middle canopy comprises Rhododendrons, *Rhus* species, *Sorbus*, *Symplocus*, *Persea clarkeana* (a type of avocado), and *Fraxinus* species. The shrub layer comprises of species such as *Berberis aristata, Daphne sureil, Eurya serrata, Sorbus, Lyonia ovalifolia, Aconogonum mollee, Edgeworthia gardenia, Zanthozxylum oxyphyllum, Viburnum*, *Smilax* spp., *Rubus paniculata*, and Rhododendrons. None of these species are considered to be endangered, protected, or endemic.
The ground cover typically comprises of a variety of species including, but not limited to, *Anemone* spp., *Galium aparine, Fragaria nubicola, Anaphalis species, Hedychium auranticum,* and *Arisaema* spp. Climbers include *Rosa brunonii, Actinida callosa, Rubia cordifolia, Vitis* spp., *Hydrangea anomala*, and *Herpetospermum pedunculosum*. Ferns species include *Pteridium asculanta, Apslenium, Suphagonus, Diplezium, Drynaria, Cythea spinulosa*, and *Adiantium* spp. There are a number of epiphytes, orchids, and mushrooms as well (a detailed list is noted Annex 2). Of all the

ground cover floral species observed, only the tree fern, *Cythea spinulosa*, is considered endangered (Bhutan conservation list). Figure 5-21 shows typical forest type and cover at the dam site (right bank of the Nikachhu). Within the elevation range typical along the banks of the Nikachhu, forest density is quite consistent. Figure 5-22 shows the typical middle canopy (Rhododendron dominating) and ground cover (in cultivated and in forest areas).

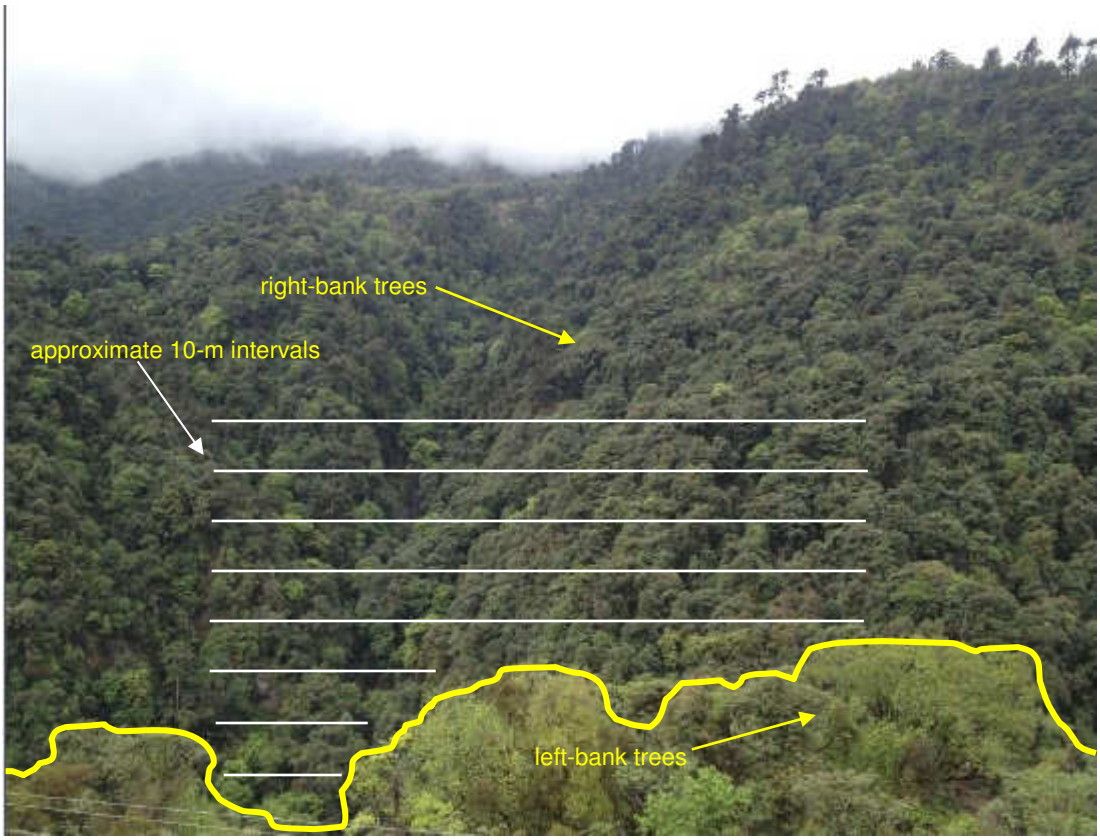


Figure 5-21: Forest type and cover typical of the left and right banks of the Nikachhu; top canopy (May 2013 at the dam site; elevation lines are at approximate 10 m intervals).

Figure 5-22: Middle canopy (left) and ground cover (middle, cultivated areas; and, right, forest areas) in the project area (July 2012 and May 2013).

5.3.3.2 Site-Specific Vegetative Cover

As required for the environmental impact assessment, vegetative cover was examined and sampled at locations which will support project activity. This was done twice for the main project component sites (in July, and in October 2012) and once for the proposed transmission line alignment (in December 2013). The study area covered the altitudinal range between approximately 1,800 and 2,550 masl, from the confluence of the Nikachhu and Mangdechhu up to the Lorim Wangdue/Trongsa National Highway point (the proposed dam site). Special attention was given to the proposed locations of the dam, adits, muck disposal sites, staff colonies, temporary camps, the surge shaft, and the powerhouse, with a focus on vegetative habitat type and any signs of disturbance. Transect lines were established at 90 degrees to the contour line, and quadrats (plots; 10 x 10m) were then sampled every 50 m. Table 5-13 provides the vegetative cover transect details (detailed field methodology is described in Annex H; observations on wildlife and other fauna were also made and are incorporated into the next section). The full results, including taxonomic lists and photographs, are included in Annex H; only the main vegetative cover features at the project sites are noted here, as the detailed taxonomic lists are not specified for each project location (instead covering the whole composite project area), and do not inform the specific possible impacts of the various project footprints on the left bank of the Nikachhu. Site-specific observations are presented first, followed by a comparative analysis of the various sites and observations on the degree of human disturbance of the vegetative cover at the sampling sites.

The transmission line survey undertaken in December 2013 included assessment of vegetation and observations or birds and wildlife (see details in Annex H; 74 plots at intervals of about 250 meters along the alignment).

Table 5-13: Vegetative cover sampling in July and October 2012.

July Transects	Length (m)	Coordinates at start of Transect		Number of plots	Highest Elevation (m)	Lowest Elevation (m asl)
		Easting	Northing			
Transect 1	250	90°22'29.30"E	27°27'1.14"N	5	2,400	2,320
Transect 2	900	90°23'14.89"E	27°27'13.59"N	18	2,404	2,248
Transect 3	890	90°24'52.64"E	27°27'9.89"N	17	2,543	2,213
Transect 4	1,000	90°26'19.78"E	27°27'8.12"N	20	2,540	2,168
Transect 5	780	90°27'24.65"E	27°28'8.48"N	15	2,555	2,319

Transect 6	1,000	90°28'46.72"E	27°29'23.67"N	20	2,502	1,814

October Transects	Location	Coordinates at Transect Start		Number of Plots	Elevation Range (m asl)
Transect 1	Dam site	90°22'11.4"	27°27'02.8"	20	2,301 - 2,342
Transect 2	Muck disposal 2	90°24'54.6"	27°26'52.9"	4	2,316 - 2,356
Transect 3	Muck disposal 3	90°26'47.7"	27°27'02.6"	11	2,160 - 2,326
Transect 4	Muck disposal 4	90°28'05.6"	27°27'57.4"	4	2,221 - 2,275
Transect 5	Muck disposal 4b	90°28'46.4"	28°27'59.1"	4	2,229 - 2,300
Transect 6	Muck disposal 5	90°28'21.7"	27°27'79.9"	7	2,155 - 2,247
Transect 7	Muck disposal 6	90°29'13.1"	27°29'36.0"	6	2,177 - 2,254
Transect 8	Powerhouse area	90°28'51"	27°28'38.3"	26	1,753 - 2,215

Dam Site Area: The dam site area is located at Sibdizim. Along with the dam, a temporary office, staff colony, labour camps, stores, and workshops will be constructed. Two muck disposal sites, as well as an aggregate crushing plant and batching and mixing plants will also be located here. This is one of the larger project sites scattered over the total footprint of the Nikachhu project. An access road (3.5 km) will link this site to the National Highway. These work areas will be located between 2,262 m and about 2,500 m asl. The vegetation at the dam site area comprises mostly evergreen oak forest, mixed with higher altitude broadleaf species. The main tree species found in this area are *Quercus griffithii, Quercus lamellose, Quercus lanata, Persea clarkeana, Acer campbellii, Alnus nepalensis, Betula alnoides, Erythrina arborescens, Lyonia ovalifolia, Persea bootanica,* and *Juglans regia*. The second (middle) canopy comprises mostly smaller trees, such as *Rhododendron arboreaum, Daphne sureil, Persea clarkeana,* interspersed with *Pinus wallichiana, Castanopsis hystrix*, and smaller oaks. The vegetation on both sides of the river is very similar (see Figure 5-21), since they are both at the same elevation. While the forest looks dense from the outside, the understorey is a not as dense, as the tree cover does not permit enough sunlight to penetrate for the understorey to flourish.

Adit 1: Adit 1 will be about one kilometer away from the dam site (to the east). Access to this adit will require clearance of a 2.6 km long road. Here, the vegetation is similar to the dam site area, and the top canopy is dominated by *Quercus griffithii, Quercus lamellose, Quercus lanata, Persea clarkeana, Alnus nepalensis, Betula alnoides, Persea species, Castanopsis hystrix,* and

Rhododendron arboreaum. The middle canopy comprises mostly smaller oak trees, *Daphne sureil, Persea clarkeana, Lyonia ovalifolia, Carpinus viminea, Viburnum, Berberis, Rubus, Hedysarum, Gaultheria, Aconogonum mollee, Eleocarpus, Ilex, a*nd bamboo. The herb and ground cover comprises mostly ferns, such as *Pteridium, Asplenium*, and *Drymaria* spp. *Eupatorium, Crassocephalus crepidioides, Cynoglossum Hypericum, Gnaphalium, Potentilla, Artemesia, Desmodium, Arisaema, Leucas, Campylotropis, Galium, Anselia, Ophiopogon,* and *Geranium* are some of the more common groundcover species. Climbers, such as *Vitis, Hemiphragma,* and *Smilax* are also quite common at the site of Adit 1.

Adit 2: Adit 2 will be located near Badela Chu, in the Taktshang Nye area. The muck disposal site has been identified for a location below the Highway. Access to Adit 2 will require clearance of a 2.6 km road. The forest comprises mostly broadleaved species, interspersed with Oaks. The dominant species here, at lower levels, include *Castanopsis hystrix* and *Castanopsis tribuloides, Quercus lamellose, Quercus lanata, Quercus griffithii, Lyonia ovalifolia, Alnus nepalensis,* and *Pinus wallichiana*. The shrub layer comprises *Berberis aristata*, *Edgeworthia gardneri, Elsholtzia fruticosa, Eurya serrata, Eurya acuminate, Gaultheria fragrantissima, Viburnum cylindricum, Viburnum cylindricum, Artemesia dubia (Besser), Rubus ellipticus,* and *Aconogonon molle.* The groundcover comprises mostly *Anaphalis triplinervis, Ainsliaea aptera, Gentiana pedicellata, Girardiania diversifolia, Eupatorium odoratum, Fragaria nubicola, Persicaria nepalensis, Hedychium ellipticum, Hemiphragma herterophyllum* and *Pteridium aquilinum.*

Adit 3: Adit 3 will be located north of Tangsibji village. It is intended that the project will widen the existing Tangsibji farm road and extend it by 2.5 km to the proposed muck disposal site. The site is located close to human settlement (north of Tangsibji village), in open and once grazed community land. There is a canal providing water for a micro-hydroelectricity project located below the National Highway, which also provides irrigation water for paddy cultivation for Tangsibji Geog. The area is used as Sokshing (forest that is used for collection of leaf litter and pine needles). The dominant trees in this area are oaks, such as *Quercus glauca, Quercus griffithii,* and *Quercus lanata,* and *Rhododendron arboreum, Erythrina arborescens*, *Castanopsis hystrix, Lyonia ovalifolia*, *and Rhus chinensis* interspersed with *Pinus wallichiana.* The understorey and shrub layer is quite sparse and mainly dominated by smaller oak trees and *Lyonia ovalifolia* and *Rhus chinensis*. The dominant shrubs are *Edgeworthia gardneri, Elsholtzia fruticosa, Eurya serrata, Gaultheria fragrantissima, Hedychium ellipticum, Hedysarum sikkimense, Saurauia napaulensis, Viburnum cylindricum, Viburnum cylindricum*, *Artemesia dubia (Besser), Rubus ellipticus, Aconogonon molle,* and *Tetradium daniellii.* The ground cover comprises mostly *Cotoneaster microphylla, Anaphalis triplinervis, Ainsliaea aptera, Gentiana pedicellata, Girardiania diversifolia, Eupatorium odoratum, Fragaria nubicola, Persicaria nepalensis, Hedychium ellipticum, Halenia elliptica*, *Inula cappa, Hemiphragma herterophyllum,* and *Pteridium aquilinum.*

Adit 4: Adit 4 will be connected to muck disposal sites 4 and 5, which will be just below the highway; therefore the length of access road required is only 990 m. The Forest in this area is mostly disturbed scrub forest; it is also heavily used for grazing. The dominant tree species are *Alnus nepalensis, Quercus griffithii*, *Betula alnoides, Lyonia ovalifolia*, *Quercus lanata, Rhododendron*, and *Benthamedia capitata.* The shrub layer comprises species like *Rhus chinensis,* smaller *Quercus,* Rhododendrons, *and Lyonia* and *Castanopsis* trees. Other shrubs include *Eurya serrata, Viburnum cylindricum, Hedysarum sikkimense, Aconogonon molle, Eupatorium odoratum,* and *Rubus ellipticus*. The ground cover is mostly dominated by *Eupatorium adenophorum, Hedychium ellipticum, Cautleya gracilis, Cirsium verutum, Bidens pilosa, Carex nubigena, Oxalis corniculata, Anaphalis triplinervis, Desmodium elegans,* and *Pteridium aquilinium.*

Adit 5: The proposed location for Adit 5 is just below the National Highway; therefore only 220 m of access road will be required to be cleared. Vegetative species biodiversity here is not high, as it is a highly disturbed scrub forest. The dominant trees are *Alnus nepalensis*, *Lyonia ovalifolia*, *Quercus lanata*, *Quercus griffithii*, *Erythrina arborescens, Benthamedia capitata*, *Daphne sureil*, *Rhus chinensis*, *Toricellia tiliifolia,* and Rhododendrons. The shrub layer comprises smaller trees, such as *Alnus*, *Benthamedia*, Rhododendrons, *Rhus chinensis, Berberis aristata, Elsholtzia fruticosa, Eurya acuminate, Eurya acuminate, Rosa brunonii, Arundinaria, Viburnum erubescens,* and *Rubus ellipticus.* The ground cover is sparse and comprises mostly *Artemesia dubia (Besser), Eupatorium odoratum, Pteridium aquilinum, Anaphalis triplinervis, Carex nubigena, Desmodium elegans, Fragaria nubicola, Hedychium ellipticum, Hedychium spicatum, Rubus ellipticus, Nepeta laevigata,* and O*phiopogon intermedius.*

Powerhouse Complex: The powerhouse complex will be located approximately 300 m upstream of the Mangdechhu dam, at Norbuodi. Although access road and facilities constructed for the Mangdechhu Hydropower Project will be used, additional access to adits and the powerhouse, labour camps, the store and workshop, powerhouse colonies, and the powerhouse cavity will be constructed. The elevation of the powerhouse complex area ranges from 1,810 to 2,400 m asl. Here the forest is mostly dominated by broadleaf forest trees and Oaks, such as *Quercus griffithii* and *Quercus lanata*. Other dominant species are *Alnus nepalensis, Betula alnoides, Rhododendron spp., Erythrina arborescens, Juglans regia, Persea bootanica, Lyonia ovalifolia, Fraxinus*, *Albizia* spp., *Magnolia, Ex-bucklandia populnea, Carpinus veminii, Macaranga* spp., and *Pinus wallichiana.* The middle story is dominated by small trees such as *Alnus nepalensis, Quercus griffithii, Quercus lanata, Rhododendrons, Erythrina arborescens, Docynia indica,* and *Lyonia ovalifolia*. The shrub layer is dominated by *Arundinaria* spp., *Eurya acuminate, Daphne sureil, Berberis aristata, Elaegnus parvifolia, Brassaiopsis mitis (Clarke), Aconogonum mollee, Symplocus paniculata, Measa chisia, Viburnum erubescens, Solanum khasianum, Rubus ellipticus, Rosa brunoii, Girardiana diversifolia,* and *Rhus chinensis*. The groundcover comprises mostly

Desmodium elegans, Artemesia, Eupatorium odoratum, Hedychium ellipticum, Pilea anisophylla, Poa annua, and *Pteridium aquilinium*, among others.

5.3.3.3 Comparative Floral Species Diversity

There were no restricted or protected species observed during the site visits or field surveys, with the only exception of the tree fern, *Cythea spinulosa*. As can be seen in Table 5-14 and Figure 5-23, the floral species diversity is highest at the proposed dam site, area with 41 species/100 m^2 and lowest at Adits 3 and 4, nearer the National Highway and human habitation. The second highest floral diversity is evident near the powerhouse area. In general, the steeper topography, less disturbed areas (the dam and powerhouse sites) have higher floral species diversity. Figure 5-24 shows the estimated tree volume at the proposed project sites. The highest tree densities were observed at Adits 1 and 2 and at the surge shaft site, being 2-3 x higher than at the dam site. Very low tree densities were observed at Adits 3 and 4, and at the powerhouse site.

Table 5-14: Summary of tree density, volume, and floral diversity from the cumulative plots.

Location	Average Tree Density per 100 m^2	Estimated Average Tree Volume (cft/m3)	Species Diversity per 100 m^2
Dam	6	6.230 m^3 (219.79 cft)	41
Adit 1	14	23.993 m^3 (846.47 cft)	30
Adit 2	16	4.933 m^3 (174.04 cft)	25
Adit 3	1	4.883 m^3 (172.27 cft)	14
Adit 4	1	4.715 m^3 (166.35 cft)	12
Adit 5	4	0 m^3 (0.00 cft)	25
Surge Shaft	12	3.239 m^3 (114.27 cft)	26
Powerhouse	2	9.279 m^3 (327.36 cft)	37

Notes: i) Diversity of species taken into consideration are those plants species enumerated in all quadrats. Species of grass and lichens have not been reflected in the vegetation list. ii) Fifty (50) centimeter girth and above are considered to be "tree" category. The biggest tree girth enumerated within the plots was a 620-centimeter oak (*Quercus glauca*). iii) 35.28 cft equals 1m^3.

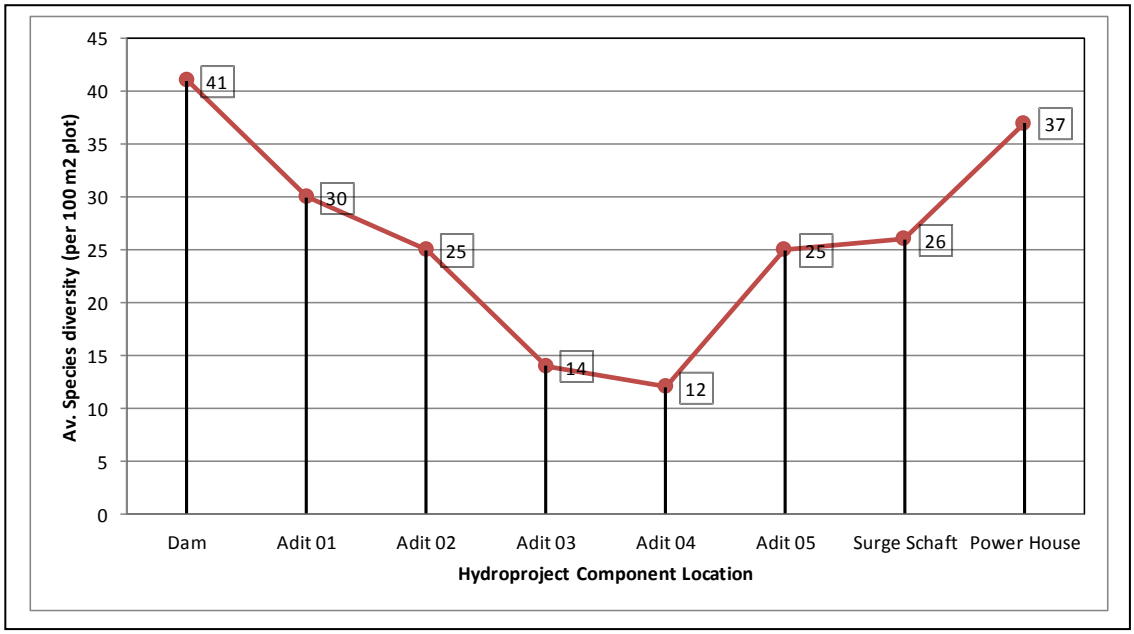


Figure 5-23: Floral species diversity at the various project component locations.

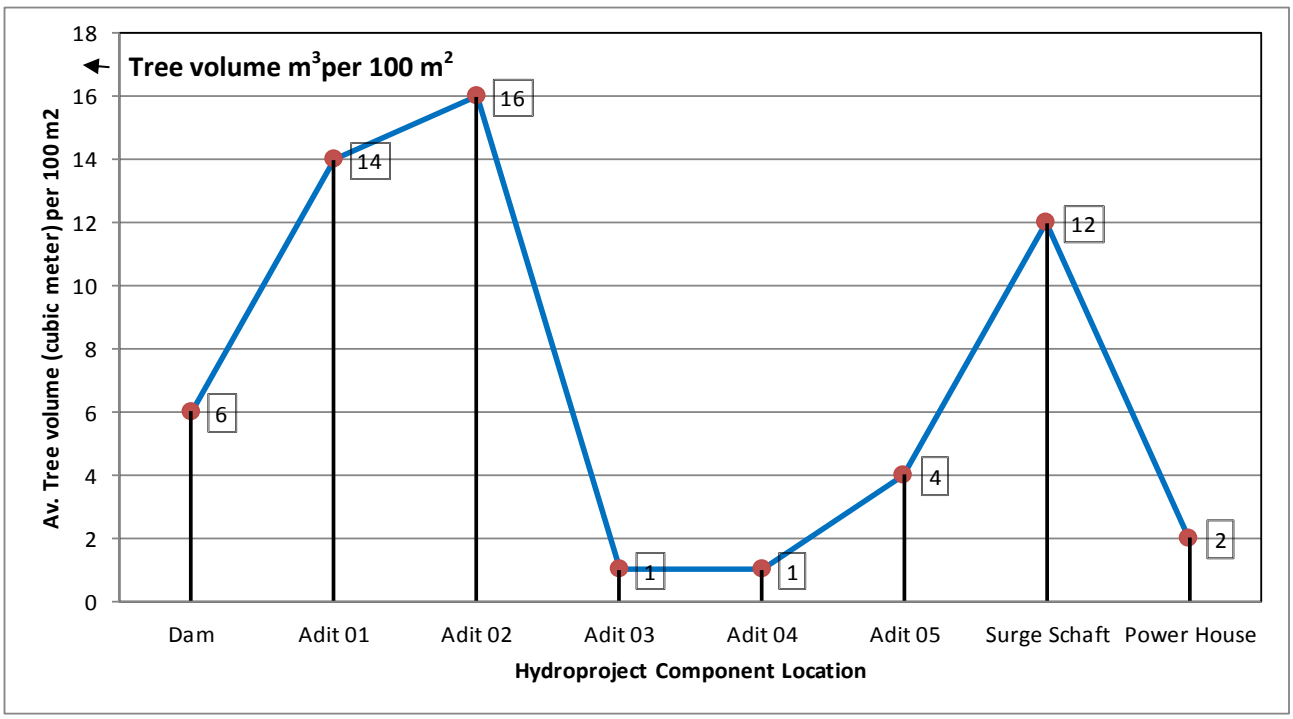


Figure 5-24: Estimated average tree volume (m^3 per 100 m^2) at the various project component locations.

5.3.3.4 Human Influence and Implications for the Forest

The main threat to forest cover and integrity is human activity. During the October 2012 survey, for each plot, the human influence in the area was recorded (see Table 5-15), according to the following categories:

0: None (no grazing, fire, logging);
1: Low (undisturbed forest, but with a few signs of human presence);
2: Medium (fairly undisturbed under-story vegetation, but with some signs of human presence);
3: High (forest is grazed, trees cut and under-story vegetation disturbed); and,
4: Very High (very disturbed and degraded habitat; highly disturbed under-story vegetation due to grazing, human activities, lopping of trees).

Table 5-15: Degree of disturbance of vegetation survey plots (October 2012).

Disturbance Category	Number of Plots	% of Plots
None	17	20.7
Low	3	3.7
Medium	0	0
High	23	28.0
Very High	39	47.6
	82	**100**

Over 75% of the plots examined in October 2012 were in disturbed areas (high or very high levels of disturbance) reflecting grazing, cutting of trees, collection of firewood or leaves for fodder. This is examined further below. Basically, the left bank of the Nikachhu (where all the proposed project facilities will be located) contains no primary forests that are ecologically intact. The forests have been heavily grazed by the cattle (reflecting the right that local people have to rear their livestock). Oaks, which are very common throughout the project area, are mainly used for fire wood. Local people still use pine for lumber (construction). Valuable timber tree species include *Exbucklandia populnea*, *Acer campbellii* (maple), and *Carpinus veminae* (ash), but they are not very common in this area. With the middle canopy, where this had been damaged, most of the regeneration comprised mainly *Alunus* sp. and *Symplocos* sp.

Some economically useful shrubs, such as *Daphne* sp., *Edgeworthii gardeneria* (which yields good material for traditional paper from its bark), and *Berberis aristata* root, collected for traditional medicine, are found in the project area, but in small amounts.

5.3.3.5 Vegetative Cover along the Transmission Line Alignment

Most of the transmission line alignment occurs in the Government Reserved land/forest, with only a few towers expected to be constructed on private land and community forest. Eighty percent of the alignment is characterized by broadleaf forest, while 15% was in scrub forest (the remaining alignment was in agricultural land or community forest or crossing a footpath or road). Along most of the alignment, disturbance was quite high, as this area is close to the cleared Right of Way for the 66 Kv transmission line from Trongsa to Yurmo (see Figure 5-25). There are also some marshy and rocky areas. The alignment also crosses a river and there are community plantations of cypress and the Taktse community forest, as well as the Eusa-Barpo community forest.

As one proceeds along the transmission line alignment (from north to south) the vegetation is mostly cool broadleaf forests; as the elevation drops and the climate is warmer, the vegetation becomes more sub-tropical, with species like *Duabanga grandiflora, Alnus nepalensis, Bischofia javanica, Rhus chinensis, Pinus roxburghii*, *Ficus roxburghii*, *Ficus semicordata*, and *Quercus lanata* in Langthel and Yurmo. Tree density is not very high at all, with a maximum of 14 trees per 100 m^2. Broadleaf forest is interspersed at intervals with scrub forest that comprises mostly *Artemesia*, *Rubus*, *Berberis*, and *Eupatorium* species.

Vegetation species recorded within and near the transmission line alignment were enumerated. The top canopy comprises mostly *Quercus griffithii, Quercus lanata, Quercus lamellosa, Alnus nepalensis, Lyonia ovalifolia*, *Daphniphyllum* species, *Docynia indica, Juglans regia, Symplocus ramosissima, Ex-bucklandia populnea, Toricellia tiliifolia, Castanopsis hystrix, Persea bootanica, Michelia doltsopa, Quercus semicarpifolia, Rhododendron arboreum, Prunus cerasoides*, and bamboo. As the elevations decreased, other species, such as *Castanopsis hystrix, Rhus wallichii, Rhus chinensis, Cinnamomum bejolghota Quercus lanata, Schima wallichii, Saurauia napaulensis, Erythrina arborescens* and (in drier areas) *Pinus roxburghii* are present.

Shrubs include *Berberis aristata, Ardisia macrocarpa, Edgeworthia gardneri, Dichroa fibrifuga, Viburnum erubescens, Mahonia nepalensis, Brassaiopsis mitis, Daphne bholua, Viburnum cylindricum, Maesa chisia, Eurya acuminatum, Rhododendron arboreum, Symplocos glomerata, Viburnum cylindricum, Ilex* species*, Cotoneaster microphylla, Elaeagnus parvifolia, Rubus ellipticus, Eupatorium adenophorum, Zanthoxylum* species*, Vaccinium myrtillus, Rhododendron vaccinoides,*

Indigofera dosua, Aconogonum molle, *Datura suaveolens, Adhatoda vasica*, and *Arundinaria* species.

Herbs along the alignment include *Artemisia vulgaris, Artemisia indica, Leucas ciliata, Inula cappa, Leucosceptrum* species*, Eupatorium adenophorum, Urtica parviflora, Anaphalis triplinervis, Cirsium falconeri, Solanum virginianum, Smilax ovalifolia, Swertia chirata, Pilea umbrosa, Ainsliaea aptera, Elatostema platyphyllum, Hedychium ellipticum, Elshotzia fruticosa, Osbeckia stellata, Oxalis corniculata, Pilea anisophylla, Colocasia esculenta,* and *Pilea umbrosa.*

Observed ground cover included *Polygonum runcinatum, Hydrocotlye javanica, Fragaria nubicola, Lycopodium clavatum* (moss), *Poa annua* (turfgrass), *Hemiphragma heterophyllum* (creeping plant), *Potentilla fruticosa, Potentilla microphylla, Tupistra chinensis, Osbeckia stellata,* and S*elaginella* sp*. (*spikemoss*),*

Climbers included *Raphidophora* species, *Hedera nepalensis*, and *Agapetes serpens*. Ferns included *Diplazium esculentum, Pteris wallichiana, Oleandra pistillaris, Gleichenia gigantean, Pteridium aquilinum*, *Drynaria propinqua, Adiantum caudatum,* and *Asplenium* sp. Observed orchids included *Calanthe* sp., *Eria coronaria*, *Phalaenopsis* sp., *Vanda cristata*, *Cymbidium cyperifolium*, *Gastrochilus* sp., *Dendrobium candidum*, *Coelogyene corymbosa*, and *Bulbophyllum* sp. Mushrooms can also be found along the transmission line alignment, including *Amanita* sp., *Lactarius piperatus, Laetiporus* sp., *Lycoperdon* sp*., Trichaptum abietinum, Boletus* sp*., Laccaria* sp*., Ramaria* sp*., Fomes* sp*.,* and *Xeromphalina campanella.*

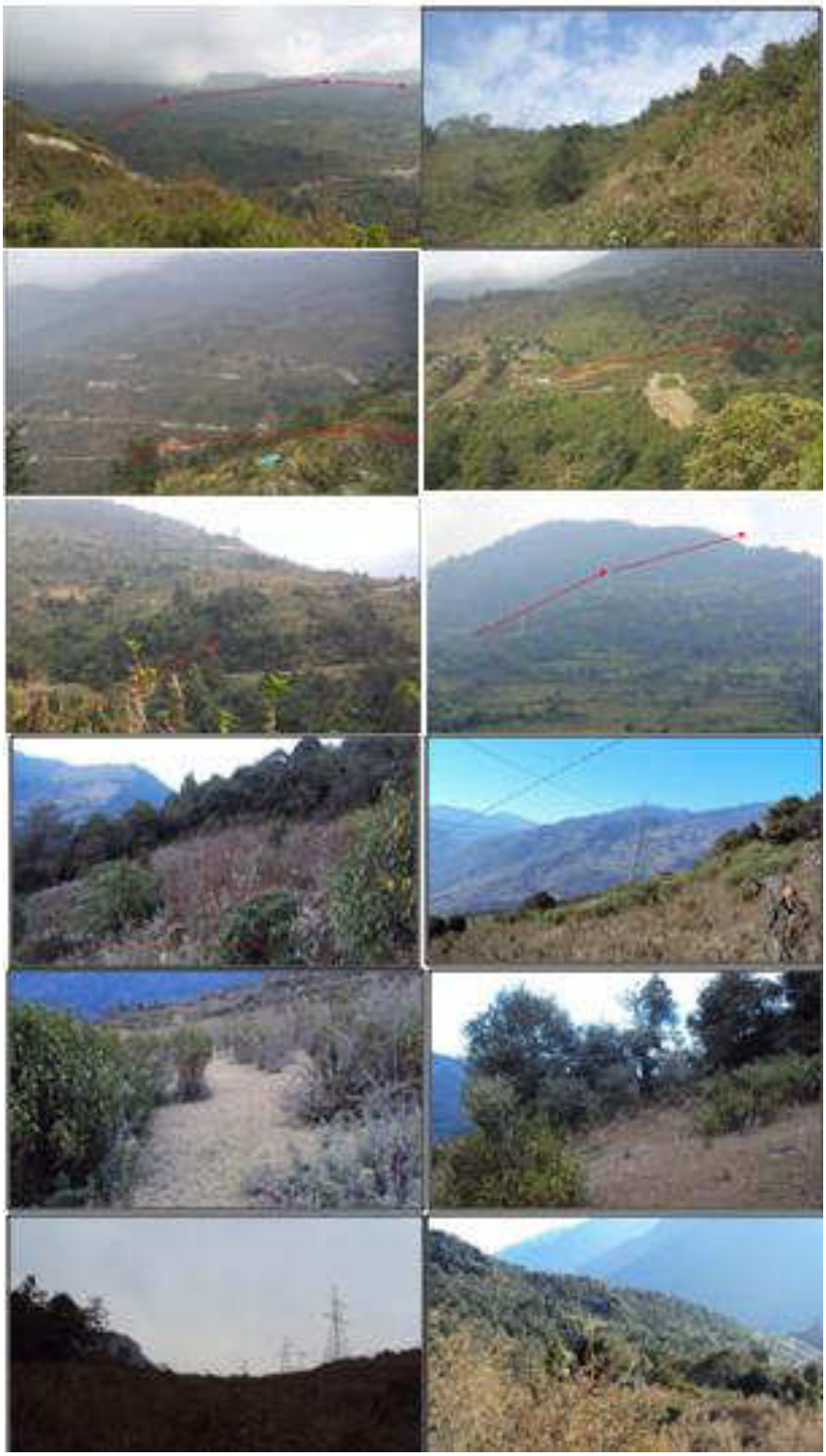


Figure 5-25: Topography and vegetation type along the proposed transmission line alignment (north to south).

5.3.4 Terrestrial Fauna

5.3.4.1 Overview of Faunal Diversity and Distribution

As noted previously, Bhutan has quite high diversity of fauna, which reflects the wide range of habitat types in the country (range of topography and temperature), as well as a high degree of protection. The system of protected areas and connecting biological corridors is designed to maintain faunal (and floral) diversity to the extent possible, especially addressing the habitat needs of endangered species, of which Bhutan has a number. The species that are protected by Bhutanese Law include Tiger (*Panthera tigris),* Leopard (*Panthera pardus*), Leopard Cat (*Prionailurus bengalensis*), Serow (*Capricornis sumatraensis*), and Himalayan Black Bear (*Ursus thibetanus*). Table 5-16 shows the status of important wildlife in Bhutan and the known presence in the project area, based on secondary data, anecdotal evidence, and the field surveys. Species that were sighted during mammals surveys conducted at the project site include Sambar Deer (fresh hoof marks and dung), Barking Deer (sighted, as well as fresh hoof marks and dung), Hory-bellied Squirrel (sighted), Stripped Squirrel (sighted), and Assamese Macaque (sighted). Other "status" wildlife species that are known to occur in the project area include the Capped Langur, Wild Dog, Goral, Gray Langur, Himalayan Black Bear, Indian Porcupine, Little Himalayan Rat, Jungle Cat, Leopard, Leopard Cat, Smooth-coated Otter, Red Panda, and Wild Pig; this information is based on anecdotal evidence provided by Park staff and local communities, which is a typical source of information, as it is very difficult to undertake a comprehensive visual inventory of larger animals. Note that other animals that have been observed in the Park, but not at the north end near the project site, and which have IUCN endangered or critically endangered, or Bhutan Schedule 1, status include the clouded leopard, spotted linsang, Chinese pangolin, musk deer, and Asian elephant.

Table 5-16: Status of important wildlife in Bhutan and apparent presence in the proposed project area.

Common Name	Scientific Name	IUCN and National Threat Category	Present in Project Area**
Asian Elephant	*Elephas maximus*	Endangered Schedule I*	No
Asiatic Golden Cat	*Pardofelis temminckii*	Near threatened	Not sighted, but reported by locals and Park staff
Indian Water Buffalo	*Bubalus arnee*	Endangered Schedule I*	No
Assamese Macaque	*Macaca assamensis*	Near threatened	Yes (sighted)
Barking Deer	*Muntiacus muntjak*	Least Concern	Yes (sighted)
Tiger	*Panthera tigris*	Endangered Schedule I*	Not sighted, but reported by locals and Park staff, 4 km away; apparently migrates to

Common Name	Scientific Name	IUCN and National Threat Category	Present in Project Area**
			south
Capped Langur	*Trachypithecus pileatus*	Vulnerable	Yes
Clouded Leopard	*Neofelis nebulosa*	Vulnerable Schedule I*	No
Dhole/ Wild Dog	*Cuon alpines*	Endangered No IUCN classification	Not sighted, but reported by locals and Park staff
Fishing Cat	*Prionailurus viverrinus*	Endangered	No
Ganges River Dolphin	*Platanista gangetica*	Endangered	No
Gaur	*Bos gaurus*	Vulnerable Schedule I*	In camera trap, according to Park staff (at the lower Mangdechhu-Nikachhu confluence)
Golden Langur	*Trachypithecus geei*	Endangered (endemic) Schedule I*	Not sighted, but reported by locals and Park staff
Himalayan Goral	*Naemorhedus goral*	Near threatened	Yes
Gray Langur	*Semnopithecus entellus*	Least Concern	Yes
Asiatic Black Bear	*Ursus thibetanus*	Vulnerable Schedule I*	Not sighted, but reported by locals and Park staff
Himalayan Musk Deer	*Moschus leucogaster*	Endangered Schedule I*	No
Hispid Hare	*Caprolagus hispidus*	Endangered	No
Indian Crested Porcupine	*Hystrix indica*	Least Concern	Yes
Little Himalayan Rat	*Niviventer eha*	Least Concern	Yes
Jungle Cat	*Felis chaus*	Least Concern	Yes
Leopard	*Panthera pardus*	Near threatened Schedule I*	Not sighted, but reported by locals and Park staff
Leopard Cat	*Prionailurus bengalensis*	Least Concern Schedule I*	Yes
Marbled Cat	*Pardofelis marmorata*	Vulnerable	No
Mouse-eared Bat	*Myotis sicarius*	Vulnerable	No
One-horned Rhinoceros	*Rhinoceros unicornis*	Vulnerable	No
Pygmy Hog	*Porcula salvania*	Critically Endangered Schedule I*	No
Red Panda	*Ailurus fulgens*	Vulnerable Schedule I*	Yes (reported in the Park by forestry staff: they are mostly located above 2,400 masl which is above the elevation of the project sites)
Sambar Deer	*Rusa unicolor*	Vulnerable	Yes (sighted)
Serow	*Capricornis sumatraensis*	Vulnerable Schedule I*	Not sighted, but reported by locals and Park staff
Sikkim Rat	*Rattus sikkimensis*	Critically Endangered Not listed with IUCN	No

Common Name	Scientific Name	IUCN and National Threat Category	Present in Project Area**
Sloth Bear	*Melursus ursinus*	Vulnerable	No
Smooth-coated Otter	*Lutrogale perspicillata*	Vulnerable	Yes
Snow Leopard	*Panthera uncial*	Endangered Schedule I*	No
Swamp Deer	*Rucervus devaucelii*	Vulnerable	No
Takin	*Budorcas taxicolor*	Vulnerable Schedule I*	No
Wild Pig	*Sus scrofa*	Least Concern	Not sighted, but reported by locals and Park staff

Schedule I* means that the species is included in the Schedule I of the Species and Nature Conservation Act of Bhutan.

** The project area is taken to mean within about 5 km of the specific project component footprints, including the JSWNP, even though the project will only encroach about 20 meters into the Park buffer zone at the inundation area above the diversion dam.

The October 2012 survey looked at specific evidence of wildlife from the proposed dam site to the powerhouse. Table 5-19 shows the summary of wildlife evidence (going from west to east); 39% of the plots had some sign of wildlife in them. The most abundant sign was that of Barking Deer, followed by Wild Pigs, Sambar, and Macaques. Wild Pigs and Macaques were also directly sighted during field visits. Wild Pigs were most common at the powerhouse site, whereas Barking Deer were encountered throughout the range of project sites from the dam to the powerhouse. Macaques were only observed at the powerhouse site. The higher level of evidence of wildlife at the proposed dam site and at the powerhouse site (see Table 5-17) coincided with the highest levels of diversity of floral species (see Figure 5-23), which would be expected (better habitat conditions). Barking Deer, Wild Pigs, and Macaques are considered to be pests by some farmers, due to the crop damage caused by them.

Table 5-17: Distribution of evidence of wildlife in the project area; going from the proposed dam site in the west (T1) to the powerhouse site in the east (T8); see legend at bottom of table.

Plot No.	T1a	T1b	T2	T3	T4	T5	T6	T7	T8a	T8b	Total Number of Plots with Evidence of Wildlife
1	D(f)	0	0	D(f)	0	0	0	0	D(f) S(f)	D(f)	4
2	0	D(f)	0	0	D(f)	0	0	0	S(f)	WP(rp)	4
3	D(f)	D(f)	0	0	0	0	0	D(f)	M(s)	WP(rp)	5

Plot No.	T1a	T1b	T2	T3	T4	T5	T6	T7	T8a	T8b	Total Number of Plots with Evidence of Wildlife
4	B(e)	0	0	WP(w)	0	0	0	D(f)	D(d)	0	4
5	WP(r)	D(d)		0			0	0	WP(rp)	WP(r)	4
6	0	0		0			0	0	0	0	0
7	D(f)	0		0			D(f)		0	0	2
8	D(d)	D(f)		D(f)					D(f)	0	4
9	0	D(f)		0					WP(r)	WP(wp)	3
10	0	0		0					D(f)	JF(d)	2
11				0						0	0
12										0	0
13										0	0
14										0	0
15										0	0
16										0	0
Number of plots with evidence of wildlife	**6**	**5**	0	3	1	0	1	2	**8**	**6**	32

Legend: D(f): Barking Deer (footprints); B(e): Black Bear (eating signs); D(d) Barking Deer (droppings); WP(w): Wild Pig (wallowing signs); WP(r): Wild Pig (rooting); WP (rp): Wild Pig (resting place); S(f): Sambar (footprints); S(d): Sambar (droppings); M(s): Macaque (sighting); JF(d): Jungle fowl (dropping).

Given the presence of the National Highway, the extent of degraded forests on the left bank of the Nikachhu, and human habitation at the eastern end of the project area, it is expected that this area is much less important to wildlife compared to the undisturbed great expanse of suitable habitat on the right bank of the Nikachhu, in the National Park, where there will be no project facilities.

Tigers are of special interest, and although not sighted in the project area, they are reported to have occurred in the vicinity. Figure 5-26 is a composite map of known tiger sightings, up to 2011. The distribution map is instructive for the environmental impact assessment. There are three main clusters of tiger sightings/distribution in Bhutan: in the northwest; the northeast; and, south-central. With regard to the Nikachhu project area, the nearest tiger sighting is about 4 km to the northwest

of the proposed dam site and then there have been two tiger sightings in the Mangdechhu valley to the east. The project site is at the southeastern tip of the northwest cluster of tiger distribution, so it is not in any of the core tiger areas, according to the sightings data. It can be seen that tigers have a quite widespread distribution throughout Bhutan (although almost no sightings in JSWNP, possibly due to lack of people there).

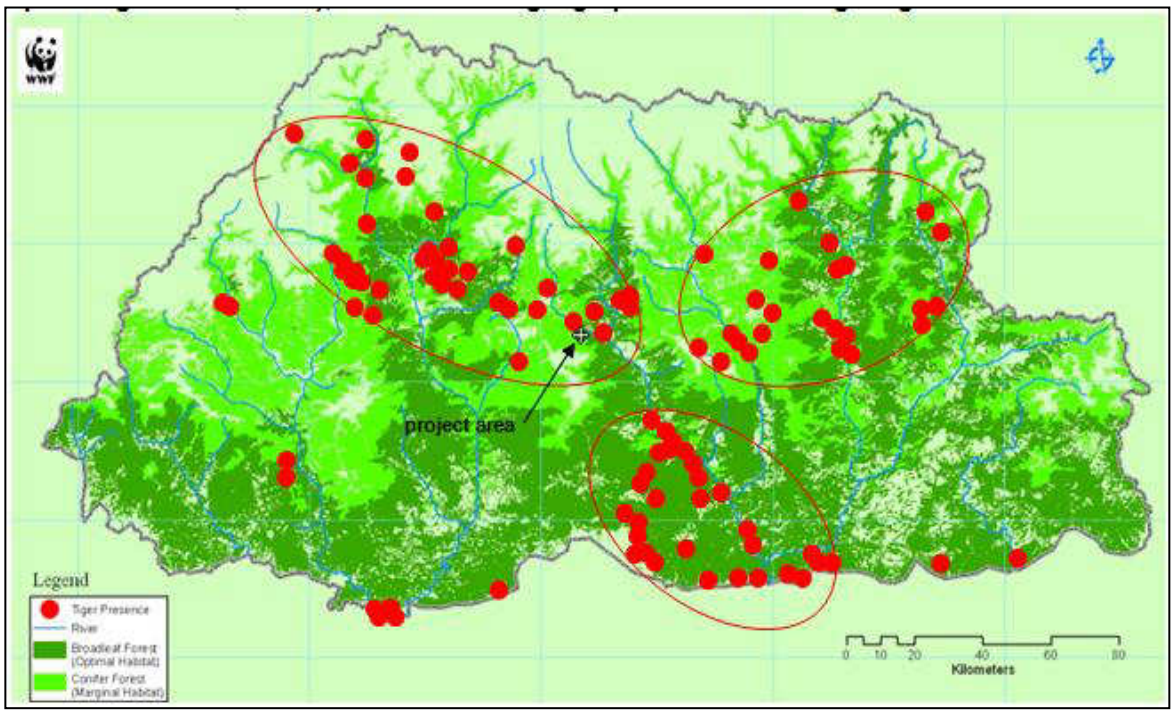


Figure 5-26: Distribution of tiger sightings (composite of surveys from the 1990s and data up to August 2011; WWF); the three main geographic clusters of sightings are shown.

Evidence of wildlife was also examined along the proposed transmission line alignment. Signs of wildlife were recorded within 31% of the 74 plots, including scat, rooting, scratching, wallowing, footprints, or nesting places, or direct sightings (see Table 5-18). Assamese macaque and Barking deer were sighted during the field surveys in December 2013.

Table 5-18: Evidence of wildlife along the proposed transmission line alignment.

Plot No.	Wildlife Species	Evidence	Number of Signs
1	Wild pig	resting place	1
2	Barking deer	dung	1 clump
7	Barking deer	dung	1 clump
7	Wild pig	rooting	1
8	Wild pig	rooting	1

Plot No.	Wildlife Species	Evidence	Number of Signs
9	Barking deer	footprint	3
12	Barking deer	dung	1
19	Barking deer	footprint	3
25	Wild pig	rooting	1
30	Wild pig	rooting	1
32	Jungle fowl	scratching	Many
33	Sambar	footprint	4
34	Barking deer	spotted	1
37	Wild pig	resting place	1
38	Wild pig	rooting	1
39	Barking deer	footprint	1
44	Wild pig	rooting	1
45	Wild pig	wallowing	1
46	Wild pig	rooting	1
49	Wild pig	wallowing	1
52	Wild pig	resting	1
55	Wild pig	rooting	1
60	Wild pig	footprint	1
65	Wild pig	rooting	1
	Total Plots		23

Given the forest types and vegetation, it is possible that other wildlife species could occur somewhere along the alignment. The tiger sighting data (Figure 5-24) do not indicate any tigers along the left bank of the Mangdechhu, where the transmission line will run.

5.3.4.2 Birds and Other Fauna

Birds and other fauna are usually less susceptible to temporary intrusions into their habitat, especially in an area where there are no unique habitats and therefore associated vulnerable birds and other fauna at risk. Birds were observed and recorded during the field surveys in July and October 2012. In general, throughout the project area, there were quite a few common birds as

expected, such as Bulbuls, Barbets, Sparrows, Warblers, Babblers, Cuckoos, Pigeons, Doves, Nightjars, Thrushes, Forktails, Redstarts, Wagtails, Choughs, Flycatchers, and Swifts. The observations of birds are summarized in Table 5-19. Table 5-20 shows birds that were only observed in July 2012, or that have been reported by local communities and Park staff (that have not been included in Table 5-19). The most abundant birds were Sibias and Yuhinas. No bird species of concern in the IUCN list were encountered (although Ward's Trogon, which is near threatened, has apparently been noted by locals) and also no migratory birds were observed (especially migratory species that travel a long distance, such as the Black Neck Crane – this was not observed).

Table 5-19: Relative frequency of observations of birds in the generalized project area, in October 2012; see key at bottom of table.

Common Name	Scientific Name	Local Abundance	IUCN status
Ashy-throated Warbler	*Phylloscopus pulcher*	C	LC
Black Drongo	*Dicrurus macrocercus*	C	LC
Black throated Tit	*Aegithalos concinnus*	LC	LC
Blue Whistling Thrush	*Myophonus caeruleus*	C	LC
Chestnut-tailed Minla	*Minla strigula*	C	LC
Chestnut-crowned Laughingthrush	*Garrulax erythrocephalus*	LC	LC
Eurasian Jay	*Garrulus glandarius*	C	LC
Great Barbet	*Megalaima virens*	LC	LC
Green-backed Tit	*Parus monticolus*	C	LC
Grey-headed canary Flycatcher	*Culicicapa ceylonensis*	LC	LC
Grey-backed Shrike	*Lanius tephronotus*	LC	LC
Hill Partridge	*Arborophila torqueola*	LC	LC
Hill Prinia	*Prinia atrogularis*	LC	LC
Large-billed Crow	*Corvus macrorhynchos*	C	LC
Lemon-rumped Warbler	*Phylloscopus proregulus*	LC	LC
Gould's Sunbird	*Aethopyga gouldiae*	LC	LC
Nepal House Martin	*Delichon nipalensis*	LC	LC
Olive-backed Pipit	*Anthus hodgsoni*	LC	LC
Oriental turtle Dove	*Streptopelia orientalis*	LC	LC
Plumbeous Water-Redstart	*Rhyacornis phaenicuroides*	LC	LC
Red-vented Bulbul	*Pycnonotus cafer*	C	LC
Rufous-bellied Niltava	*Niltava sundara*	LC	LC
Rufous Sibia	*Heterophasia capistrata*	A	LC
Russet Sparrow	*Passer rutilans*	LC	LC
Short-billed Minivet	*Pericrocotus brevirostris*	LC	LC
Spotted Forktail	*Enicurus maculates*	LC	LC

Common Name	Scientific Name	Local Abundance	IUCN status
Striated Laughingthrush	*Garrulax striatus*	LC	LC
Streaked Laughingthrush	*Garrulax lineatus*	C	LC
Verditer Flycatcher	*Eumyias thalassina*	LC	LC
White-tailed Nuthatch	*Sitta himalayensis*	LC	LC
Whiskered Yuhina	*Yuhina flavicollis*	A	LC
Whistler's Warbler	*Seicerus whistleri*	C	LC
White-throated Fantail	*Rhipidura albicollis*	LC	LC
White Wagtail	*Motacilla alba*	LC	LC
Yellow-bellied Fantail	*Rhipidura hypoxantha*	LC	LC
Yellow-billed Blue Magpie	*Urocissa flavirostris*	LC	LC
Yellow-browed Tit	*Sylviparus modestus*	LC	LC

Key: LC: Less Common (0-25% of transects); C: Common (26-50% of transects); FA: Fairly Abundant (51-75% of transects); A: Abundant (>75% of transects). IUCN status: LC means Least Concern.

Table 5-20: Additional birds observed only in July 2012, or which have been reported by local communities or park staff.

English Name	Scientific Name	Sighted During July Survey	Reported by Locals
White- throated laughing thrush	*Garrulax albogularis*		X
Grey bushchat	*Saxicola ferrea*	X	
White- collared blackbird	*Turdus albocinctus*	X	
Wedge-tailed green pigeon	*Treron pompadora*		X
White-browed fulvette	*Alcippe vinipectus*		X
Oriental cuckoo	*Cuculus saturates*	X	
Streak-breasted scimitar babbler	*Pomatorhinus ruficollis*		X
Common hoopoe	*Upupa epops*	X	
Blue-capped rock thrush	*Monticola cinclorhynchus*	X	
Long-tailed shrike	*Lanius schach*	X	
Long-tailed minevet	*Pericrocotus ethologus*	X	
Steppe eagle	*Aquila nepalensis*	X	
Broad-billed warbler	*Acrocephalus aedon*		X
Golden-throated barbet	*Megalaima franklinii*		X
Crimson sunbird	*Aethopyga siparaja*		X
Black bulbul	*Hypsipetes leucocephalus*		X

English Name	Scientific Name	Sighted During July Survey	Reported by Locals
Blue rock thrush	*Monticola solitaries*	X	
Rufous-vented tit	*Parus rubidiventris*	X	
Rufous-winged fulvette	*Alcippe castaneceps*		X
Hoary-throated barwing	*Actinodura nepalensis*		X
Stripe-throated yuhina	*Yuhina gularis*	X	
Grey-cheeked warbler	*Seicercus poliogenys*	X	
White-rumped munia	*Lonchura striata*		X
Ward's Trogon	*Harpectes wardi*		X

Other smaller fauna that have been observed (and expected) in the project area include at least three species of snakes (mostly observed killed on the highway) and some amphibians (these are documented in Annex 2; observations were incidental during the tree and wildlife surveys; no IUCN status reptiles and amphibians were observed; there are no amphibians or reptiles listed in the JSWNP faunal records).

Surveys for amphibians and reptiles were undertaken for the Mangdechhu hydropower project (to the east of the Nikachhu project area). As expected, those surveys indicated amphibians in moist places and near water bodies. Observations included the Flat tailed Gecko (*Hemidactylus platyurus*) and the common Garden lizard (*Calotes versicolor*), as well as lizards such as the Eastern green calotes (*Calotes jerdoni*), Commno skink (*Mabuya carinata*), and Draco (*Draco dussumieri*), Snakes included the Green Keelback (*Macropisthodon plumbicolor*), Banded Krait (*Bungarus fasciatus*), and Python (*Python molurus*).

Tadpoles of frogs were observed during the Nikachhu aquatic survey but it was not possible to determine taxonomic identity (possibly *Amolops* sp., since this group of frogs inhabits mountain rapids). Other species of frogs observed during the Mangdechhu survey included the East Asian Tree Frog (*Polypedates leucomystax*), Giant tree frog (*Rhacophorus maximus*), Himalayan torrent frog (*Amolops marmoratus*), Himalayan bull frog (*Pea leibigii*), Tree frog (*Polypedates spp.*), and Leaping frog (*Rama erythraea*).

With regard to butterflies, 49 species have been reported from the Trongsa Mangdechhu area. These are mainly in the families Papilionidae, Nymphalidae, Pieridae, Hesperidae, and Lyeaenidae. These species tend to not be seen frequently during the monsoon and post-monsoon season, but have been recorded in other studies in the area. There is also a diverse insect fauna (in addition to butterflies) in the area, that includes numerous moths, beetles, flies, dragonflies and damselflies, various kinds of bugs, ants, bees, and wasps. These are very numerous, not especially specific to

unique habitats, and pervasive, so they are expected throughout the project area and are usually considered to be resilient (given their large numbers and short life spans). Detailed numerical taxonomic surveys are therefore not warranted.

Birds were also observed, of course, along the proposed transmission line alignment. At total of 123 species of birds was recorded in December 2013 (see Annex 2). Only the Rufous-necked Hornbill (*Aceros nepalensis*) is listed as "Vulnerable" in the IUCN Red List. It is a totally protected species listed in Schedule-I of the Forest and Nature Conservation Act of Bhutan (1995).

5.3.5 Aquatic Fauna

5.3.5.1 Introduction

Given that the main interaction of the Nikachhu project and the environment will be the alteration of the Nikachhu hydrology, the aquatic habitats and fauna (mostly fish) in the project area were surveyed, twice, as follows: in June-July 2012, and in December 2012. Information was also obtained from an earlier survey in 2010. The river above the proposed dam, just before the confluence of the Nikachhu and Mangdechhu, and also the Mangdechhu itself (near the Mangdechhu project tailrace site) were examined. Detailed methodology, lists, locations of sampling, and photographs are noted in Annex I; only the main details pertinent to environmental impact assessment are described below.

5.3.5.2 River Habitat

Section 5.2.6 provides details on the hydrology and river profile for the Nikachhu. The steep drop in elevation over the length of the river that will be affected by the project, the prevailing cross-section of the Nikachhu before the confluence with the Mangdechhu, and the seasonal variability of the river discharge are determinant factors for the aquatic habitat, especially as it pertains to fish. Figure 5-29 shows the gradation of the Nikachhu habitat from Chendebji to the confluence with the Mangdechhu. At Chendebji, the river is relatively wide and shallow, and marked by a cobble bottom, with areas of gravel and coarse sand. In this area, slightly above Chendebji, there are approximately 30 households that collect aquatic vegetation (locally called "chhuru"), which is then sold in the market.

The Nikachhu then enters a narrower gorge, with higher velocity, larger boulders and bedrock on the riverbed, and occasional pools (for example, at Lorim). At that point, the Nikachhu enters a long series of cascades and falls (for example, near Bangla Pokto), and then grades to a wide and shallow river again, with cobble and small boulders, at the confluence of the Nikachhu and Mangdechhu. For fish, the most critical factor that determines distribution and migration range is

the presence of natural barriers (such as falls and cascades, exceeding 3 meters in height[9]). As noted previously, a drop of 30 meters, apparently near Bangla Pokto, is known to prevent any upstream fish migration beyond this point. As the first cascades and waterfalls on the Nikachhu, above the confluence with the Mangdechhu, occur about 100 meters upstream of the confluence, it is unlikely that fish can continue upstream past that point.

The field survey in December 2012 included estimates of river width, depth, and flow. The estimated average river width of the Nikachhu (at different sites) ranged from about 14 to 30 meters. The estimated depths (at the beginning of the lean season) ranged from 1.5 to 3 meters. The flow velocity of the Nikachhu was estimated at 1 m/s to 2.5 m/s.

Figure 5-27: Gradation of river character and habitat change over the length of the Nikachhu (left to right; at Chendebji; Lorim; near Bangla Pokto; at the confluence of the Nikachhu and Mangdechhu).

[9] Dr. D.B. Gurung, Dean, Academic Affairs, College of Natural Resources, Lobesa.

5.3.5.3 Fish

The only fish caught during the first survey (July 2012) was the brown trout (*Salmo truta*; only from a location above the proposed dam site; not at the confluence with the Mangdechhu and not in the Mangdechhu itself). This dominance by one fish species was further confirmed through different consultations and discussions with the local community and Mr. Phuntsho (from Chendebji, once in-charge of the Royal fishing spots). The brown trout was introduced to the Nikachhu in the late 1960s (it is originally a European species). Mr. Phuntso noted that while fish cannot migrate up the Nikachhu, due to the waterfalls, the brown trout may have migrated downstream as far as the confluence with the Mangdechhu (although none of the Nikachhu project surveys or the Mangdechhu project survey recorded it at the confluence or in the Mangdechhu). Furthermore, given the relatively high altitude (very few fish are expected above 2,000 m asl), cold water, and rough conditions in the Nikachhu, important fish such as the mahseer (*Tor* sp.), do not occur there. The Mangdechhu has more fish, being a bigger river at lower altitude, and asla (*Schizothorax progastus*), snow trout (*Schizothorax richardsonii*), and copper mahseer (*Acrossocheilus hexagonolepis*) are listed for that river, as well as other mahseers, catfish, carp, and some smaller resident fishes. These do not manage to get up the Nikachhu, as waterfalls start about 100 meters from the confluence. Fish sampling in December 2012 confirmed that the only fish in the Nikachhu above the confluence with the Mangdechhu is the brown trout (and it was only found at the dam site and above, not at the confluence itself). The December 2012 survey also confirmed the common presence of snow trout (*Schizothorax richardsonii*) in the Mangdechhu. Given the difficulty in accessing the Nikachhu and the lack of fish, as well as the high cost of a fishing license, local people generally do not fish in the Nikachhu.

5.3.5.4 Other Aquatic Fauna

The field surveys included observations of tadpoles (frog juveniles), especially in ditches along the highway and at the confluence of the Nikachhu and Mangdechhu. These would be expected in the slower moving water and pools in the area. The December 2012 survey also indicated the extensive presence of macroinvertebrates (especially insect larvae). The most abundant were Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies). Odonata (dragonflies and damselflies), Megaloptera, and Diptera (true flies) were also common at various points along the Nikachhu. Various aquatic worms and flat worms (planarians) were also evident. Stoneflies, especially, are sensitive to pollution, and their presence reflects the good water quality observed in the Nikachhu. Various kinds of zooplankton were also observed in the Nikachhu December 2012, including ciliates, rotifers, and chrysomonads. The presence of these other aquatic fauna is expected and reflects a pristine aquatic environment.

5.4 Socio-Economic Aspects

5.4.1 Introduction

The socio-economic assessment of the Nikachhu project was carried concurrent to the environmental assessment. Details are provided in Annex J. The main points relevant to the assessment are summarized below, to provide the baseline. There are two elements to the description of socio-economic aspects in the project area: an overview of the socio-economic context in the project area, based on secondary data and statistics; and, consultations with local people, specific to their exposure to the project.

5.4.2 Socio-Economic Overview

5.4.2.1 Land Use, Industry, and Agriculture

Most of Trongsa Dzongkhag (87.6%) is covered by forest, leaving only 5.7% for agriculture, 3.6% as Tsamdro (pasture), 0.1% for settlements, with the remaining 3% covered by rocky outcrops and water bodies. The dominant agricultural practice in this area is Kamzhing, or dry land cultivation, followed by Chhuzhing (wetland cultivation). Tseri farming (slash and burn cultivation) is also practiced in some areas. The total land cultivated is 2,287.2 acres (915 ha; NSB, 2011). In terms of area, the most important crops grown in the project area are paddy (rice), maize, buckwheat, wheat, and barley. Other crops, grown to a lesser extent, include potatoes, chili, radish, and other green vegetables. Perennial crops consist mostly of oranges, guava, banana, and cardamom (Atlas of Bhutan, 1997). Livestock rearing also plays a very important role in supporting rural livelihoods in the project area. More than 90% of the households own livestock, which provide farmyard manure and draft power, while the butter and cheese produced from these animals is an important source of cash income for the farmers.

The towns (including Trongsa) contain nine small industries, of which four are agriculture-based, four are forestry-based, and one is mineral-based. There are a few car repair workshops, but no heavy industry and no major manufacturing. There are 69 small licensed contractors. There are also ten hotels and eight restaurants.

5.4.2.2 Infrastructure

Infrastructure is better developed in the towns than in the rural areas, because of the technical difficulties presented by the mountainous terrain, and the proportionally high cost of providing services to scattered communities. The government is, however, committed to providing for the needs of the rural population, and has made significant progress over the past few decades. For example, around 94.8% of households now use improved sources of drinking water, such as piped drinking water and community standpipes in smaller villages. Like most other dzongkhags, there is

no centralized sewerage system in Trongsa. Individual houses have septic tanks in the towns, and mainly self-built pit latrines in the villages, which are normally located in a wooden or sometimes just bamboo enclosure away from the house. The Mangdechhu Hydropower Project is currently under implementation (just north of Trongsa) with major infrastructure works, such as tunnels and access roads, being constructed. There are three micro-hydro stations at Kingarabten, Sherabling and Tangsibji.

Only 23.6% of households use electricity for cooking, while 21.8% use LPG, and 54.2% of the households use fuelwood for both heating and cooking. Less than 1% uses kerosene. There is some drainage infrastructure in the towns, consisting mainly of open concrete drains alongside the roads and shops, and, in some villages, earth drains fulfill the same function. The local district is responsible for solid waste collection in the urban areas, whereas in rural areas, people generally burn their waste, or deposit it on open ground.

5.4.2.3 Roads and Transportation

The total road network in Bhutan amounts to 8,381.60 km of road. Of this, 39% comprises farm roads, many of which have been constructed during the past decade. The Primary and Secondary National Highway comprises 27% of this road network. The remaining 34% comprises district roads, forest roads, and access roads. Trongsa town is along the main East-West Highway. The district has a total of 326.35 km of road network. This includes 164 km of National Highway, 24 km of district roads, and 122.82 of farm roads; the remainder comprises power tiller tracks, access roads, or urban roads.

5.4.2.4 The Tourism Industry

There are 741 registered tour operators in Bhutan, but only 318 were operational in 2012. There are at least 8,818 people directly employed and apparently 13,227 indirectly employed by the tourism industry. The highest number of tourists visiting Bhutan was recorded in 2011, with visitor arrivals peaking at 64,028 (BTM, 2011), representing a growth of 56.7% over the previous year. Most visitors come from the United States, followed by Japan, China, the United Kingdom, Germany, Thailand, Australia, France, Singapore, and Canada. In terms of visits to the districts, Trongsa ranked sixth, with 6,454 visitors in 2011, with 58.7% visiting during the months of September to November, and 26.9% visiting during the March-May period.

5.4.2.5 Demography

Trongsa is typical of most dzongkhags, as it contains a small main town and large areas of countryside in which people live in small scattered communities. The population was 14,977 in 2011, with 7,609 males and 7,368 females (which is close to the natural 1:1 ratio). The rural

character of the area is reflected by the fact that there are only 589 households in the urban areas, compared to 2,468 households in rural areas. The population density is only 8 persons/km^2.

The population of Bhutan includes many ethnic groups, such as the Sharchops from the east, Ngalongs from the west, Khengpas from the central region, nomads from the north, and Lhotshampas from the south. These (and others) are all found in Trongsa dzongkhag, especially due to the large influx of non-residents. Because of the mix of ethnicities, a wide variety of dialects is spoken, of which Dzongkha, Khengkha, Sharchop, and Nepali are the most common. With the new hydropower projects in the region, there has been a large influx of Indian labour.

5.4.2.6 Health, Education, and Other Facilities

The only hospital is in Trongsa town, which has two doctors and a room for two beds. There are six Basic Health Units (BHUs- level II) in the geogs, and 22 Out-Reach Clinics (ORCs) in some of the larger villages. There are also 3 Units that provide indigenous treatment and services.

There is only one higher secondary school, one middle secondary school, 3 lower secondary schools, 4 primary schools, and 15 community schools (totaling 24 schools) in the district. 3,405 students were enrolled in these schools last year. There are also 46 non-formal education centers. There are various other centers providing training and extension services in agriculture and forestry/natural resources, including Renewable Natural Resources (RNR) Centers, veterinary hospitals, animal husbandry centers, and Agriculture Extension services.

5.4.2.7 History and Culture

Until the early 17th century, Bhutan was the battleground of warring tribes that were later unified by Shabdrung Ngawang Namgyal, a Tibetan lama and military leader, who came to Bhutan in 1616. He established the dual system of government, in which the power was shared by an administrative leader and a spiritual leader together. Ugyen Wangchuck, the Penlop of Trongsa, was the first hereditary monarch of Bhutan. He came to power in 1907 and, since then, Bhutan has had five Monarchs. From a constitutional monarchy, the country transitioned to a democracy after its first elections in March 2008.

As a country, Bhutan places very high emphasis on its culture and believes that its future sovereignty as a nation state will continue to depend on its cultural identity. Bhutanese traditions include the rituals, customs, dress, code of etiquette, religious ceremonies, and customs, among others (Chophel, 2012) and its traditional values have always been largely shaped by Buddhist concepts. To preserve its unique age-old culture and traditions, the Institute for Culture was established in 1961. The country is dotted with numerous Buddhist religious and cultural sites, some of them dating back to the 17th century. Each district has special religious celebrations called

Tsechus during which traditional mask dances are performed on auspicious days. These dances and festivals provide an important means to impart knowledge to the public.

Trongsa Dzong, which was built in 1648, is famous as the seat of power over Central and Eastern Bhutan during the reign of both the first and second kings. All four kings had been invested as Trongsa Penlop ("governor"), prior to ascending the throne. The Trongsa Dzong currently holds 28 religious altars in its premises. Another famous structure is the Ta Dzong, a watchtower built in 1652, which once guarded Trongsa Dzong from internal rebellion. It has four observation points resembling the Tiger, Lion, Garuda, and Dragon and is now a museum. The Late King Jigme Dorji Wangchuck was born and spent his childhood in the Threupang Palace, while the Chendebji Chorten, which lies en route to Trongsa, was built in the 18th century by Lama Zhida, apparently to cover the remains of an evil spirit that was subdued at this spot.

There are no physical cultural resources in and near the project sites. The nearest such cultural resource is 6 km away in Chendebji (as noted above).

5.4.3 Stakeholder Analysis and Consultations

5.4.3.1 Approach

Various approaches and methodologies were used to determine the specific socio-economic aspects of the resident population which may be exposed to the project. These are summarized below (see Annex J for more details).

Stakeholder Analysis: A stakeholder is any person, group or institution that has an interest in a development activity, project, or program. This definition includes intended beneficiaries and intermediaries, winners and losers, and those involved or excluded from decision-making processes. The stakeholders were met and information was collected, either in focus groups or in key informant interviews. Table 5-21 summarizes the stakeholders and nature of engagement during the study.

Table 5-21: Stakeholder, by type and engagement.

Stakeholder	Stakeholder Type	Engagement During Study
DGPC	Primary	Discussions on the project and secondary data collection.
Local government (Tangsibji, Drakten)	Secondary	Views on the project and its development prospects. Participation in the project.

Stakeholder	Stakeholder Type	Engagement During Study
Community members exposed to project	Primary	Perceptions on benefits and adverse impacts. Views on compensation packages. A survey in the catchment villages (roughly 30% sample of households of both impacted and non-impacted households to establish the socio-economic baseline). A census of all impacted persons, their property and discussions to gather their views, hopes and fears about losses.
Businesses	Secondary	Perceptions on benefits and adverse impacts on their livelihoods. Sampled business by category (hotels, shop keepers, contractors, taxis).

Consultations: Consultations were an important component of the social impact assessment. These events were crucial to test acceptance or opposition to the project by beneficiaries.

Socio-Economic Survey: This was necessary to understand the socio-economic profile of the people living in the area where the project will be implemented. From the socio-economic profile, the core social issues could be accentuated, such as the economic status and socio-economic differentiation of people, to categorize and to focus on the truly vulnerable populations based on variables such as age, marital status, income, employability, food security, land holdings, disability, and income. From the survey, information on the perceptions of people regarding the project could be aggregated, to ascertain the level of "buy-in" to the project. Finally, potential impacts on people and their property or livelihoods could also be identified through the survey.

Household Survey: The primary method used for the socio-economic assessment was the household sample survey method, wherein the sample of respondents to be interviewed was pre-calculated to determine the number of respondents to interview. The respondents were selected randomly from the frame which consisted of the villages that could benefit or would be impacted directly by the project (e.g., villages in Tangsibji geog) and villages that would indirectly benefit or be impacted by the project (e.g., villages in Drakten geog). The survey team used a structured socio-economic survey questionnaire as the primary tool to collect quantitative data. The sample representation was 73% of the total. Preceding the survey, enumerators were trained in survey methods and techniques. The tools for the survey were discussed in detail in the language to be used in interviews at village level. Data were collected by a survey team comprising 6 enumerators, 1 supervisor, and the consultant over a period of one week. After verification, the data were then transferred to SPSS for data summary and preliminary analysis. Further details are provided in Annex J. The interview respondents were 71% female and 29% male (see Figure 5-28).

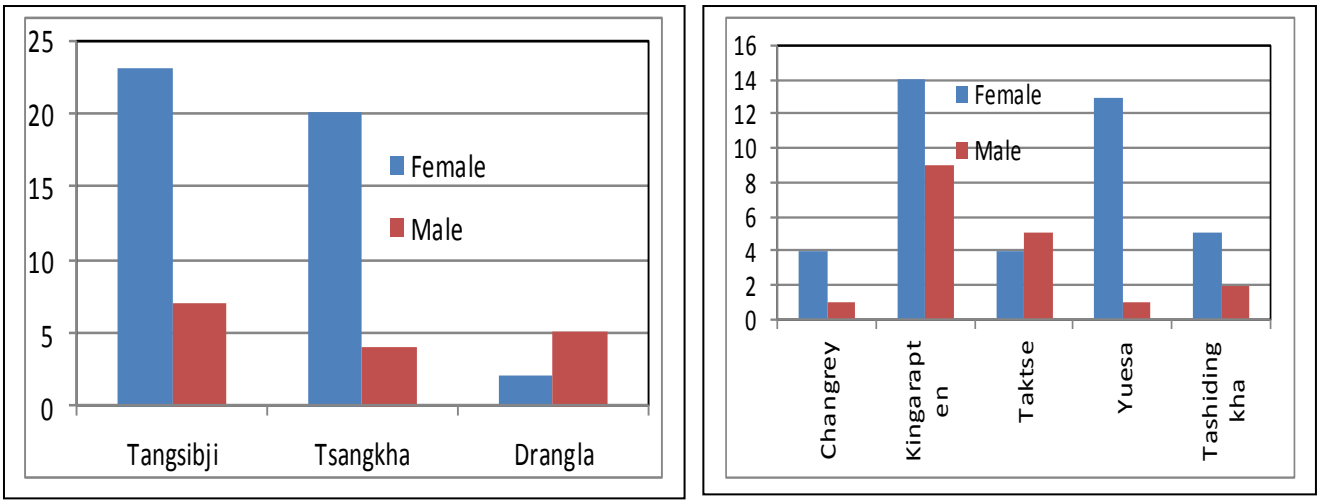


Figure 5-28: Interview respondents in Tangsibji Geog (left) and Drakten Geog (right).

5.4.3.2 Results

Of 127 respondents consulted, 69 female respondents were head of the household and 34 male respondents were head of the household, while the rest of the respondents were just members of the household; 39% were sons or daughters (see Figure 5-29). Regarding marital status, 53% were married and 29% unmarried.

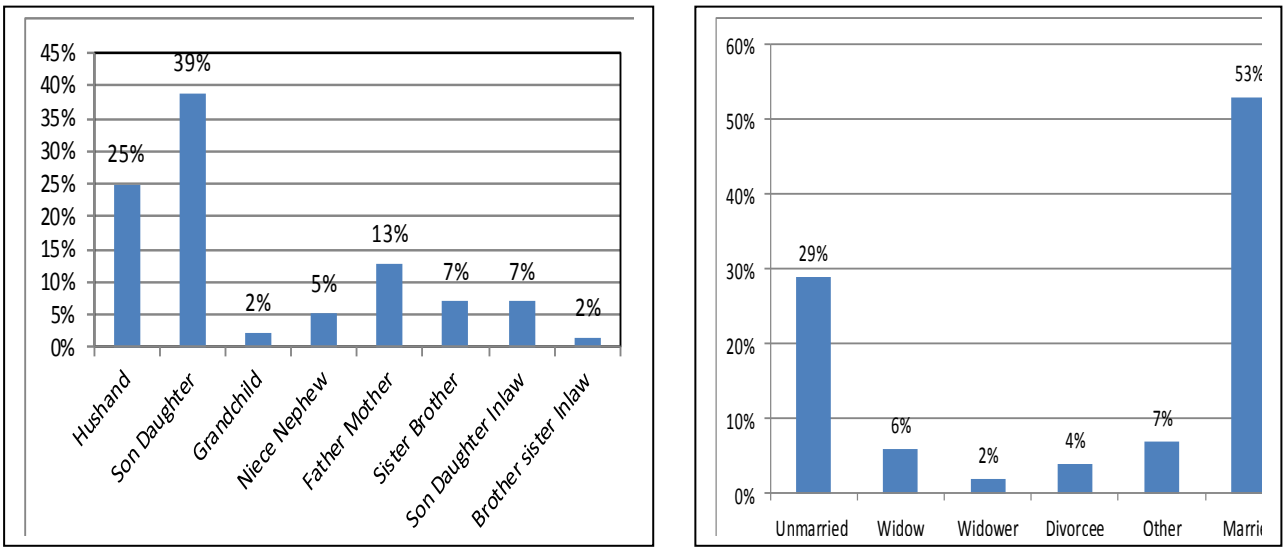


Figure 5-29: Relationship of household (HH) members to HH head and marital status.

The population structure of respondents was as follows: 24% below 15 years; 17% above 61 years; and, 16% between 26 and 36 years (see Figures 5-30 and 5-31).

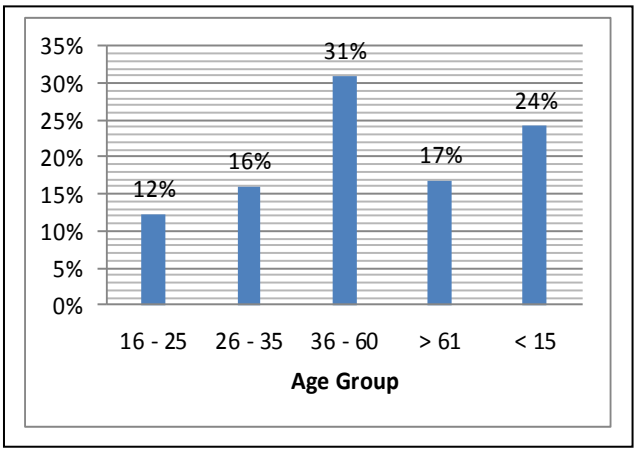


Figure 5-30: Population by age group.

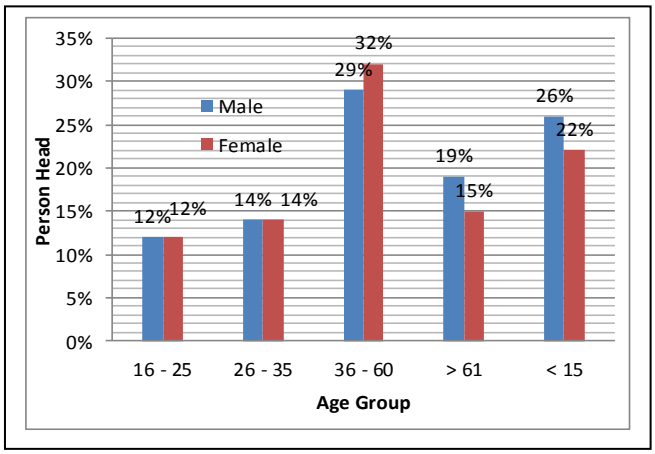
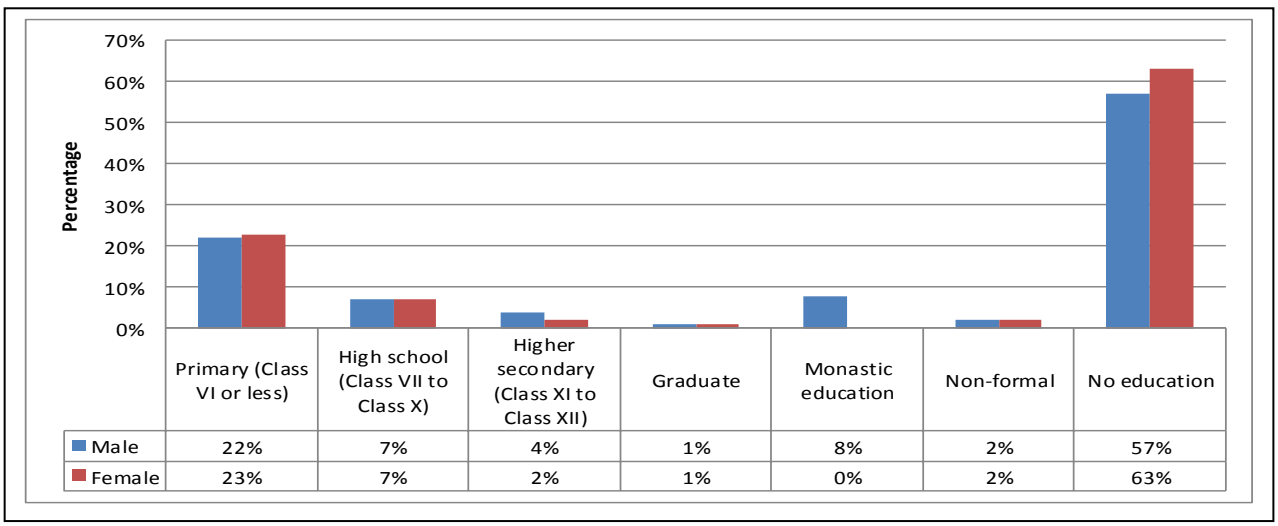


Figure 5-31: Female and male ratios.

In terms of occupation, 66% were farmers, while 22% were students, 1% was monk, 1% was a civil servant, 2% were in business, and 8% were otherwise categorized. Regarding occupational skills, 47% had no skills, 4% had skills in carpentry, 1% in masonry, 9% in weaving, and 39% were in other categories. Among the female population, 63% had no education, while among the males, 57% had no education (see Figure 5-32).



	Primary (Class VI or less)	High school (Class VII to Class X)	Higher secondary (Class XI to Class XII)	Graduate	Monastic education	Non-formal	No education
Male	22%	7%	4%	1%	8%	2%	57%
Female	23%	7%	2%	1%	0%	2%	63%

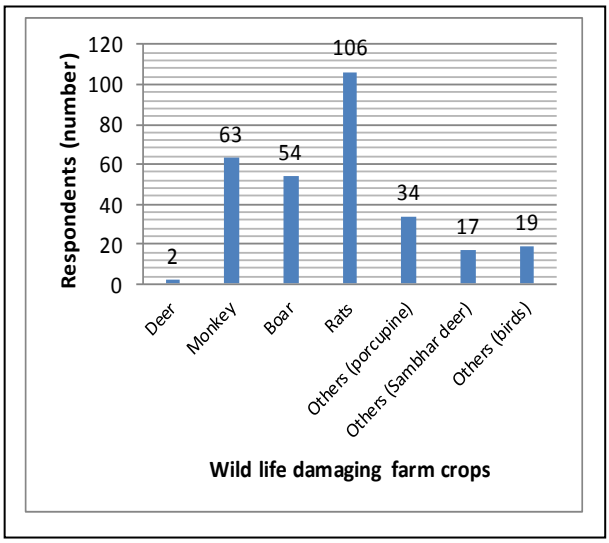
Figure 5-32: Education qualifications (male and female).

Land Ownership and Utilization: Sharecropping is not commonly practiced. The data indicate that the area of land utilized for farming is not optimal. The proportion of land cultivated to land owned, in terms of dry land, ranges from 69% to 72%. Similarly, between 70% and 75% of the wet land is cultivated by both affected and non-affected households. Land utilization therefore is not optimized. Inadequate household labor, hilly terrain hindering effective farm mechanization, and wildlife predation on crops, are some of the reasons that farmers leave land fallow.

Agricultural Production: Overall, the paddy yield shows a median yield of 883 kg/acre, whereas the median yield of maize is 1,120 kg/acre. The Tangsibji geog average yield per acre for rice is 1,053 kg/acre, while the maize yield is 798 kg/acre. The national average for paddy yields is 1,122 kg/acre while for maize it is 866 kg/acre. The data reflect the fact that while paddy yields are not up to the geog and national averages, the study area farmers have yields of maize higher than the geog and national average yields. Further, only small quantities of mainly a few types of vegetables, such as potato, chili, cabbage, greens, and beans are sold; most seems to be consumed at the household level, except for chili and potatoes, 46% to 70% of which is sold. In general, commercial vegetable production is not really practiced at the moment, suggesting a subsistence form of agriculture in which most is consumed in the household and a small production surplus is sold in the market.

Farmers in the project area are noted to use very low quantities of inorganic fertilizers (average of 18 kg used) and chemical pesticides (average of less than half a kg), suggesting an organic form of farming is in practice. Other inputs, such as improved seeds and seedlings, are used. Mechanization in this area is also low, with very few farmers owning power tillers, rice hullers, threshers, winnowers, and oil expellers. The data show that, overall, 92 respondents use irrigation channels to irrigate their paddy, but 71 farmers (77%) mentioned that the water was not enough for irrigation, especially during transplantation, mainly due to limited water received from the source (which may reflect the variable intensity of rainfall in any given year). There are also issues with seepage, which reflects ineffective maintenance of the canals.

One of the pressing issues is wildlife predation on crops, which has remained an unresolved problem until now. It is believed by villagers that the health of the local forests, as well as the extent of forest coverage in the district (which currently stands at 84%) and the strong conservation policies (ban on poaching of animals) has led to an increase in wild animals. The data below show the types of animals damaging crops (Figure 5-33). Rats, monkeys, boars, and porcupines seem to be the common predators on crops. Farmers also lose livestock to wildlife, as elsewhere in the country (see Figure 5-34).



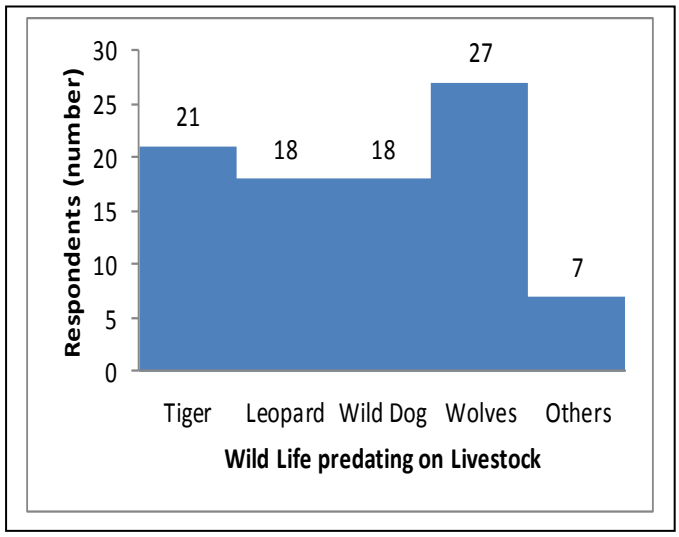


Figure 5-33: Wildlife damaging crops.

Figure 5-34: Wildlife predating on livestock.

Housing and Access to Services: Irrespective of being affected or non-affected (by the project), the majority of the houses were constructed in the last two decades, especially over the period between 1992 and 2002, and all the houses built during this period have CGI roofs, stone walls, and stone and wood floors. This is the typical type of house in the project area. On average, villagers had 8 rooms for dwelling purposes, excluding the kitchen and toilet, which by Bhutanese standards, is fairly well endowed in terms of space and size of houses. The type and size of houses can be considered as an economic indicator; generally, the communities visited, especially in Tangsibji geog, own well-built large houses (they are considered to be "well-off"); see Table 5-22.

Table 5-22: Type of housing owned.

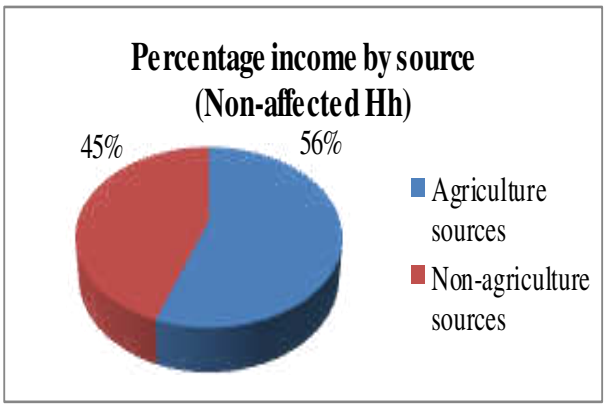
Type of house owned	Type of Respondent													
	Project Affected						Not affected							
	Year House Constructed category						Year House Constructed category							
	1992 to 2012		1972 to 1991		Total		1992 to 2012		1972 to 1991		1971 or before		Total	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%
CGI roof, stone walls and stone/wood floors	8	80	2	20	10	100	76	70	22	20	10	9	108	100
CGI roof, wood walls and wood floors	0	0	0	0	0	0	2	100	0	0	0	0	2	100
CGI roof, cement walls and floors	0	0	0	0	0	0	7	100	0	0	0	0	7	100
Total	8	80	2	20	10	1	85	73	22	19	10	9	117	100

In terms of access to other basic services, such as safe drinking water, sanitation and electricity, the data reveal that all households covered in the survey had access to electricity and sanitation.

There were, however, 5 non-affected households and 1 affected household without access to drinking water. The facilities present in the geog are relatively proximate and accessed within a one-hour walk from the villages. The district head office is a one-hour drive from Tangsibji and about a 2-hour drive away from Kingarapten. In descending order of frequency of visits per year (by local families) , the most visited facilities are: the road (average of 102 times); market (10 times); community school (4 times); primary school (3 times); forest range office (2 times); and the Renewable Natural Resources Center, Out Reach Clinic, Hospital, and Dzongkhag (once).

Access to Credit and Savings: Farmers have access to economic institutions and instruments, such as credit and loans. Four project-affected households, on an average, availed loans of around Nu. 27,778, and 33 non-affected households took loans averaging Nu. 57,223. Most took loans for reasons such as house renovations, to buy improved breed dairy cattle, to make business investments, and a few borrowed money for the education of their children. All loans were from the banks. Farmers saved a median amount of Nu. 10,000, used mainly for education of children, consumption, conduct of religious ceremonies, medical treatment, purchase of agricultural inputs, and house renovation.

Income, Asset Ownership and Expenditure: The median income earned from agricultural sources was substantially more (roughly double) than that earned from non-agricultural sources. This suggests that there is huge scope for further enhancing income from agricultural activities, such as horticulture and dairy farming, since a ready market would be created, once there is an influx of workers for the various hydropower projects. However, farmers also need to make investments in such enterprises and therefore the question of assets, savings, and loans comes into play, to take advantage of the market created by various projects. Figures 5-35 and 5-36 depict income from the two sources analyzed; potentially affected and non-affected households are quite similar.



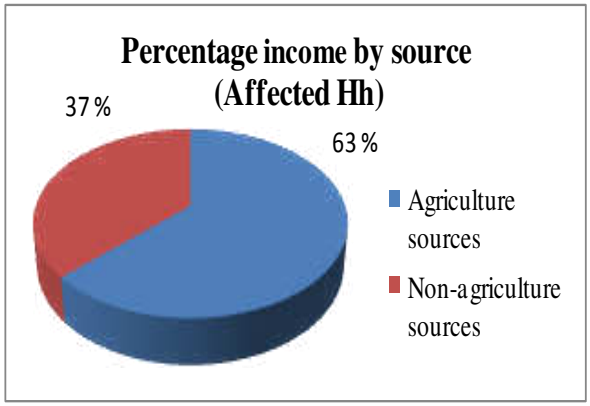


Figure 5-35: Income for non-affected HH. Figure 5-36: Income for affected HH.

The assets owned by households in the project area include radio, TV, refrigerator, bicycle, motorbike, car, mobile phone, rice cooker, water boiler, foreign bow, alter, bukhari, electric iron,

electric fan, rice mill, sewing machine, tractor, machine plow, thresher, winnower, insect pump, and jewelry. About 62% owned a radio and 68% owned a TV. Regarding expenditures, the expenditures on consumption (food, clothing and children's education) are much less than non-consumption expenditures (health, service bills, transportation, religious ceremonies, taxes, fuels, house maintenance, labor hire, production inputs). The farmers in the affected category seem to spending slightly higher, on average, than the non-affected households. As a percentage share of the total expenditure, non-affected households spend 79% on non-consumption items, while affected households spend 73% on non-consumption items.

Enterprise: A rapid assessment of the type of enterprises operating in the project area revealed that there are 8 shops in Tashiling and Tsangkha. There are also two shops and one tourist resort between Chendebji and Tashiling. There are 3 RNR product sales outlets (which are basic sheds constructed with government assistance) from which farmers at the moment sell dairy produce. On the periphery of the project area, in Bjizam, there is one shop and between Bjizam and Trongsa there is one tourist resort and one general shop. Between Tsangkha and Bjizam, there is one resort and one hotel.

Trongsa Dzongkhag, according to data received from the Ministry of Economic Affairs in Trongsa, has 465 service categories of enterprises, 262 contract businesses, 22 production and manufacturing enterprises, 293 small retail traders, and 46 micro-trade enterprises. The commencement of various hydropower projects is expected to increase the volume of business transactions in Trongsa.

Vulnerability: The discussion on vulnerability is important from a social development perspective. Development projects can aggravate the socio-economy of vulnerable populations, through differential impacts of the development. Here, several types of vulnerabilities that could possibly be triggered by shocks, income poverty, land ownership, widowhood, disability, productive capacity are briefly discussed (these receive attention in Part 3: Resettlement Plan). The common shocks experienced at the moment include crop failure (69%), and death of livestock (33%).

Disability: In total, 13 persons in the sample area reported a disability; nine of these were women. The disabilities that are prevalent include blindness (4 persons), deafness (2), dumbness (2), lameness (4), and hunched (1).

Poverty: The data on show that 7 households, from among the non-affected households, have incomes that are below the national poverty line of Nu. 1,097.00 per month (or Nu. 13,164.00 in a year). Most of these households are in Drakten geog, which is an indirect beneficiary of the Nikachhu HPP. Widowhood or divorce can enhance the vulnerability of women. The data show that

there were 33 women who were widowed; there were 20 divorcees. The area of land owned and cultivated has implications not only for food security but also for income, especially if livelihoods are land-based. It was found that 13 households reported owning land less than an acre.

6 SUMMARY OF ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS AND PROPOSED MITIGATION MEASURES

6.1 Introduction

The accurate prediction and assessment of environmental and socio-economic impacts (in an objective manner) is at the core of this exercise for the Nikachhu Hydropower Project: to help determine the acceptability of the project, and to ensure that any residual impacts are properly recognized and addressed by appropriate mitigation measures. The process involves proper use of three information sources:

- the environmental baseline data summarized in Chapter 5 (and detailed in various annexes), especially noting scale of features, uniqueness, and potential vulnerabilities;
- the project description of the Nikachhu Hydropower Project provided in Chapter 2 (especially the nature, location, and duration of construction activities, and project design features in effect throughout operation); and,
- lessons learned from observations of construction and operation of other hydropower projects in Bhutan and elsewhere (especially detailed analysis of the Dagachhu project elements and the construction at the Mangdechhu site).

A process of examining all possible interactions between all project components, in all phases (pre-construction, construction, and operation) and the environmental and socio-economic features in and near the zone of influence of the project was then used as a “filter”, to sharpen the impact assessment focus on the critical interactions, and to separate out the less important interactions. Less important interactions are usually the ones that self-correct over time, due to the short-term nature of some interactions and the resilience of certain features. Scientific judgment was then applied to this process (especially using previous ecological knowledge of linkages and responses in ecosystems), in order to determine the likely outcomes of project/environment/socio-economic interactions, their importance (significance of impacts), and the required mitigation measures. The assessment used the following notions of “significance” and “ability to mitigate” to help isolate those interactions of concern (needing attention), and those which are acceptable (without any specific mitigation required).

A *major impact* can be considered as follows: (for environmental resources) the project affects an entire population or species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any other populations or species dependent upon it, to its former level within several generations; or (for social values), the project affects a subsistence

or commercial resource use, business activity, or social behaviour to the degree that the well being of the user or local community is affected over the long term. These kinds of impacts are difficult to mitigate, except by changing location or significantly altering project design.

A *moderate impact* (less significant) can be considered as follows: (for environmental resources) the project affects a portion of a population or habitat and may bring about a change in abundance and/or distribution over one or more generations, but does not threaten the integrity of that population, or any population dependent upon it; or (for social values), a short-term effect upon the social and economic well being of resource users or local communities using the project area may also constitute a moderate impact, but from which recovery is expected within 3-6 months. These kinds of impacts can be mitigated or may be acceptable without mitigation, if recovery can be assured.

A *minor impact* can be considered as follows: (for environmental resources) the project affects a specific group of localized individuals (plants and animals) within a population or a habitat over a short time period (one generation or less), but does not ultimately affect other trophic levels or the population itself; or (for social values), activities of resource users or local communities in the project area are not affected measurably beyond a minor disturbance of resource use or local activities, from which recovery is relatively quick. Impacts of this nature are often amenable to mitigation, or require no mitigation at all.

These definitions embody the concept of recovery from impact. Basically, a habitat or population that can recover fairly quickly from a project impact is not considered to be significantly impacted. Also, if the habitat or population affected is only a small percentage of the total population or habitat in the immediate area (perhaps 1-2%), and there is continuity of habitat in affected areas with adjacent habitat in unaffected areas (providing a refuge for affected species), then the impact can also be considered insignificant, as it would likely not be visible or measureable within the spatial and temporal variability of habitat quality and function, and it would not create a barrier (at this scale) to access to adjacent similar habitat, which can provide a buffer or compensating function. To help assess impact significance, for each project activity, all possible interactions with the environment are considered; this means direct and indirect impacts (the latter requiring other conditions to be in place for an impact to occur), and cumulative impacts (the results of project interactions being added to the possible environmental impacts of other projects and planned development in the area). With regard to socioeconomic parameters, if a project activity causes a negative impact in one parameter which can be compensated by an overall positive development impact, then the impact can usually be considered to be acceptable.

This section provides the results of the impact assessment exercise described above, including the overview of project/environment/socio-economic interactions (Section 6.2), specific expected impacts, and the required mitigation measures (which are then taken up in the Environmental Management Plan in Part 2). Note that the mitigation measures described in this Volume are responsive to the identified impacts, and their rationale is explained in order to justify their selection. These mitigation measures are then elaborated on an issue-and-site specific basis in the EMP, along with related performance indicators which will inform the required monitoring programs to evaluate their effectiveness.

6.2 Overview of Interactions Between the Project and Environmental/Socio-Economic Features

As noted above, all project activities in all phases were examined for possible interactions with all physical, biological, and socio-economic parameters (described in Section 5). The interactions were rated for possible positive impacts, negative impacts (but mitigatable), and major negative impacts that cannot be mitigated. The results of this analysis are shown in Table 6-1.

There are two ways of initiating the analysis of potential impacts. In the first instance, for each project activity, in each phase, the possible impacts on each of the physical, biological, and socio-economic features in the zone of influence can be described (requiring repetition of description of similar impacts from different sources). In the second instance, for each physical, biological, or socio-economic feature, all possible impacts, from different project activities, can be tallied up and described, which requires just one description of the accumulated effects of various projects activities (less repetition of impact narrative). These different entry points to the impact narrative are shown in Table 6-2. By initiating the impact analysis using both methods (by project activity, and by baseline parameter), there is assurance that all possible interactions between the project and environmental and socio-economic features are addressed. The most important potential impacts are then described in Section 6.3, with assessment of scale and significance, and description of the required mitigation measures (which are then described on a site-specific basis, to the extent possible, in the EMP).

Table 6-1: Summary matrix of environmental and socio-economic impacts.

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES			
0	**+**	**-**	**X**
No significant negative impact (transient, or high recovery potential, or small ratio loss) and there is no significant public concern.	Significant positive effect.	Negative impact that can be mitigated to acceptable levels (moderate or minor).	Significant negative impact that cannot be mitigated (major).

MATRIX OF IMPACTS

	PHYSICAL							**SOCIO-ECONOMIC**						**BIOLOGICAL**							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/ Services**		**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
Pre-Construction																					
Land acquisition: temporary.	0	0	0	0	0	0	0	-	-	0	0	0	0	-	-	-	-	-	0	0	
Comments: All temporary land acquisition will revert to rehabilitated or wild state after construction.																					
Land acquisition: permanent.	0	0	0	0	0	0	0	-	-	0	0	0	0	-	0	-	-	-	0	0	
Comments: Permanently acquired land will be converted to staff quarters, facilities, and project buildings, rather than wild state.																					
Land clearing and cuts (work sites	-	0	-	-	0	0	-	-	-	+	+	0	-	-	-	-	-	-	-	0	

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

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No significant negative impact (transient, or high recovery potential, or small ratio loss) and there is no significant public concern.	Significant positive effect.	Negative impact that can be mitigated to acceptable levels (moderate or minor).	Significant negative impact that cannot be mitigated (major).

MATRIX OF IMPACTS

	PHYSICAL							**SOCIO-ECONOMIC**						**BIOLOGICAL**							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/**	**Services**	**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
and access roads).																					
Comments: The main concern is sediment mobilization and erosion.																					
Influx of workers (worker camps).	0	0	0	-	0	0	-	0	0	+	0	-	-	0	0	0	0	-	0	-	
Comments: Risk of social instability, poaching, waste.																					
Construction equipment mobilized.	0	0	-	-	0	0	0	0	-	0	0	0	-	0	-	0	0	-	0	0	
Comments: Mostly a concern with noise and emissions; dust.																					

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

0	+	-	X
No significant negative impact (transient, or high recovery potential, or small ratio loss) and there is no significant public concern.	Significant positive effect.	Negative impact that can be mitigated to acceptable levels (moderate or minor).	Significant negative impact that cannot be mitigated (major).

MATRIX OF IMPACTS

	PHYSICAL							SOCIO-ECONOMIC						BIOLOGICAL							
Project Activities	Slope/ Sediment Stability	Climate	Air Quality	Noise Levels	Hydrology	Groundwater	Surface Water	Use of Farm Land	Aesthetics	Business/	Services	Social/ Cultural Stability	Health/ Safety	Biodiversity	Protected Areas/ Biological	Vegetative Cover/ Diversity	Forest Resources	Wildlife, Terrestrial, Avian	Aquatic Habitats	Fish Stocks/ Migration	
Fuel storage.	0	0	0	0	0	-	-	0	0	0	0	0	-	0	0	0	0	0	-	-	
Comments: Risk of spill.																					
Construction																					
Influx of more workers (worker camps).	0	0	0	-	0	0	-	0	0	+	0	-	-	0	0	0	0	-	0	-	
Comments: Risk of social instability, poaching, waste.																					
More construction equipment used.	0	0	-	-	0	0	0	0	-	0	0	0	-	0	-	0	0	-	0	0	
Comments: Mostly a concern with noise and emissions; dust.																					

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

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MATRIX OF IMPACTS

	PHYSICAL							SOCIO-ECONOMIC						BIOLOGICAL							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/**	**Services**	**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
More fuel storage.	0	0	0	0	0	-	-	0	0	0	0	0	-	0	0	0	0	0	-	-	
Comments: Risk of spill.																					
Blasting.	-	0	0	-	0	-	0	0	0	0	0	0	-	0	-	0	0	-	0	0	
Comments: Temporary disturbance; noise; risk of slope failure.																					
Quarry operation.	-	0	-	-	0	0	-	-	-	0	0	0	-	0	0	-	0	-	0	0	
Comments: Mostly a concern with noise and dust; truck traffic.																					
Crusher plant operation.	0	0	-	-	0	0	-	0	-	0	0	0	-	0	0	0	0	-	0	0	
Comments: Concern for noise and dust; truck traffic.																					
Muck generation	-	0	-	-	-	0	-	-	-	0	0	0	-	0	-	0	0	-	-	0	

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

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MATRIX OF IMPACTS

	PHYSICAL							**SOCIO-ECONOMIC**						**BIOLOGICAL**							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/ Services**		**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
and disposal.																					
Comments: Concern is for slope stability and proper containment.																					
River diversion (cofferdam).	0	0	0	0	-	0	-	0	0	0	0	0	0	0	-	0	0	0	-	-	
Comments: Temporary disturbance of river.																					
Transmission line tower installation (land clearing).	-	0	0	0	0	0	0	-	-	0	0	0	0	-	0	-	-	-	0	0	
Comments: A patchwork of small “footprints”.																					
Operation																					

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

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MATRIX OF IMPACTS

	PHYSICAL							SOCIO-ECONOMIC						BIOLOGICAL							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/**	**Services**	**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
Reduced worker numbers (just permanent staff).	0	0	0	0	0	0	0	0	0	-	0	+	0	0	0	0	0	0	0	0	
Comments: Diminishing local supplier business.																					
Reservoir operation (flooded area).	0	0	0	0	-	0	-	0	+	0	0	0	-	0	-	-	-	0	+	+	
Comments: Option for new fish stock area; recreation area.																					
Water intake to headrace.	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

0	+	-	X
No significant negative impact (transient, or high recovery potential, or small ratio loss) and there is no significant public concern.	Significant positive effect.	Negative impact that can be mitigated to acceptable levels (moderate or minor).	Significant negative impact that cannot be mitigated (major).

MATRIX OF IMPACTS

	PHYSICAL							SOCIO-ECONOMIC						BIOLOGICAL							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/**	**Services**	**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
Comments: Risk of fish intake.																					
Diversion dam operation.	0	0	0	0	-	0	-	0	-	0	0	0	0	0	0	0	0	0	-	-	
Comments: Blocking fish movement; reduced downstream discharge.																					
Maintenance of minimum environmental flow.	0	0	0	0	-	-	-	0	-	0	0	0	0	0	0	0	0	0	-	-	
Comments: Reduced downstream discharge; alteration of river width for habitat.																					
Occasional	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	-	-	

Title: **Nikachhu Hydropower Project**	Recipient Country **Bhutan**	Organization **DGPC**	Location **Trongsa**

DESCRIPTION OF CODES

0	+	-	X
No significant negative impact (transient, or high recovery potential, or small ratio loss) and there is no significant public concern.	Significant positive effect.	Negative impact that can be mitigated to acceptable levels (moderate or minor).	Significant negative impact that cannot be mitigated (major).

MATRIX OF IMPACTS

	PHYSICAL							SOCIO-ECONOMIC						BIOLOGICAL							
Project Activities	**Slope/ Sediment Stability**	**Climate**	**Air Quality**	**Noise Levels**	**Hydrology**	**Groundwater**	**Surface Water**	**Use of Farm Land**	**Aesthetics**	**Business/**	**Services**	**Social/ Cultural Stability**	**Health/ Safety**	**Biodiversity**	**Protected Areas/ Biological**	**Vegetative Cover/ Diversity**	**Forest Resources**	**Wildlife, Terrestrial, Avian**	**Aquatic Habitats**	**Fish Stocks/ Migration**	
sediment purging.																					
Comments: Occasional turbidity pulses in downstream river.																					
Risk of dam burst.	-	0	0	0	-	0	-	0	0	0	0	0	-	0	0	0	0	0	-	-	
Comments: Low probability; concern for human safety.																					
Maintaining cleared right-of-way for transmission line.	0	0	0	0	0	0	0	-	-	0	0	0	0	0	0	-	-	-	0	0	
Comments: Stunted vegetation and reduced wildlife habitat.																					

Table 6-2: Summary of impacts associated with each project activity (entry of analysis by activity), and summary of the possible accumulated impacts for each physical, biological, and socio-economic parameter (entry of analysis by baseline parameter).

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
Pre-Construction	
1. Land acquisition: temporary.	• Impacts are due to loss of access and clearing vegetation, leading to: • Reduced use of farm land (pasture) during construction period (then access again). • Reduction in visual aesthetics of current lands (going to roads, truck traffic, construction sites). • Temporary loss of habitat and associated biodiversity, due to vegetation clearing, including a small segment in the biological corridor; tree clearing (to be compensated); possible temporary disturbance of terrestrial wildlife during construction activities. • Then, all temporary land acquisition areas will revert to rehabilitated or wild state after construction.
2. Land acquisition: Permanent.	• As above (#1), except there will be no permanent land acquisition in the biological corridor. So, • Impacts are due to loss of access and clearing vegetation, leading to: • Permanent reduced use of farm land (pasture); compensated. • Reduction in visual aesthetics of current lands (less appealing visuals, due to staff quarters, facilities, and project buildings). • Limited permanent loss of habitat and associated biodiversity, due to vegetation clearing; tree clearing (to be compensated); areas no longer accessible or attractive to terrestrial wildlife. • In summary, permanently acquired land will be converted to staff quarters, facilities, and project buildings, rather than wild state, but with tree and shrub planting to mitigate.
3. Land clearing and cuts (work sites and access roads).	• As in #1 and #2 above, land clearing is the requisite activity after acquisition. Impacts in #1 and #2 above apply; in addition, • The main concern is sediment mobilization and erosion, possibly leading to: • Slope instability and sediments entering forested areas and creeks and rivers (reduced water quality due to turbidity and possible occlusion of aquatic habitat, until sediments are flushed naturally). • Generation of dust (transient). • Associated noise (transient). • Health and safety issues associated with construction, as well as local

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
	communities using the access roads. • When land clearing is complete, access roads are finished, and facilities are in place, all of the above impacts and risks are neutralized. Furthermore, the construction activity and access roads will increase local business and improve transportation services (mostly in the eastern end of the project area, where there are more people). • All identified project work sites are at least 150 meters from watercourses (a minimum of 30 m is required in Bhutan). • Bhutan road construction guidelines will apply, and will be conditions of contract for the road builders.
4. Influx of workers (worker camps).	• Risk of social instability (with first wave of workers), poaching of fish and wildlife near work sites, and generation of waste (risk of reduced water quality from sewage), and noise. • Health and safety issues associated with construction work. • On the other hand, increased business opportunities associated with worker consumption.
5. Construction equipment mobilized.	• Mostly a concern with noise, emissions, and dust; all transient and in sporadic occurrence, although centred on work sites; vehicles may transport mud and sediments to other locations, if not washed properly on-site. • Distances to nearest inhabited buildings are still to be surveyed (April, 2014). • Health and safety issues associated with construction equipment (accidents). • Poor aesthetics of vehicles and equipment in a pristine environment. • Equipment in the biological corridor may inhibit wildlife movements.
6. Fuel storage.	• Risk of spill, if not properly controlled and bunded; risk of contamination of groundwater and surface water (aquatic habitat compromised; possible impact on brown trout). • Explosion risk.
Construction	
7. Influx of more workers (worker camps).	• As in #4 above, except that numbers ramp up and risks increase accordingly. • Water requirements will increase, but these will be sourced from tributaries of the Mangdechhu and Nikachhu, at locations downstream from other users of these water sources (overall consumption will be less than 25% of the discharge of these tributaries, and most water, about 60%, will go back into the watershed). • Sewage treatment facilities in worker camps will be located as far away as possible from watercourses.
8. More	• As in #5 above, except that more equipment over a longer period will be

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
construction equipment used.	activated, so risks increase accordingly.
9. More fuel storage.	• As in #6 above, except that the risk of a spill increases (higher volumes in more locations).
10. Blasting.	• Generally, this can be managed with few or no impacts, but a residual concern for "knock-on" effects, such as slope instability, noise and risk of wildlife disturbance, possible fracturing of bedrock and alteration of existing aquifer dynamics (groundwater). • Associated health and safety risk. • DGPC now has experience in blasting methods, from the Dagachhu and Mangdechhu hydropower projects, which can minimize the area in which there are percussion and vibration effects.
11. Quarry operation.	• The possible quarry location is still being finalized. • As in #3 and #5 above; mostly a concern with noise and dust; truck traffic on public roads. • Risk of localized land slips; some vegetation clearing may be necessary; risk of disturbance of wildlife. • Possible sediment run-off to local creeks and streams (turbidity and reduced quality of aquatic habitat). • Loss of public access to adjacent land. • Reduced visual aesthetics in adjacent areas. • Health and safety issues for quarry workers.
12. Crusher plant operation.	• Concern for noise and dust; truck traffic, although localized. • Risk of sediment mobilization to local creeks and streams, and possibly the river (turbidity and reduced quality of aquatic habitat). • Reduced visual aesthetics in adjacent areas. • As with other work sites, health and safety issues for workers. • Disturbance of terrestrial wildlife in immediate area.
13. Muck generation and disposal.	• Concern is for slope stability and proper containment (it is more significant for this activity than any of the others); disposal sites will require preparation and containment structures (retaining walls) before muck is disposed; • Risk of sediment entry to local creeks and the river (restricted hydrology and turbidity plumes leading to negative effects on aquatic habitat, albeit transient). • Dust and noise will be generated (mostly trucks and dumping). • More difficult access to areas adjacent to muck disposal sites.

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
	• The muck disposal sites present poor visual aesthetics until such time as they are terraced and re-vegetated. • Health and safety issues (especially truck drivers and dozer operators). • Temporary occlusion of part of the biological corridor (possible disturbance of terrestrial wildlife movements).
14. River diversion (cofferdam).	• To enable construction of main dam, the river has to be diverted by constructing temporary cofferdams and a diversion tunnel. This is a temporary arrangement, and the actual de-watered section will be about 170 m long. Water is diverted to its original course after completion of the dam and appurtenant structures. • This is a standard method being adopted for all the hydropower projects including mega hydropower projects like Punatsangchhu and Mangdechhu where the dewatered stretch between the inlet and outlet of the diversion tunnel is more than a km long. In the case of Nikachhu, this stretch is only about 170 m.
15. Transmission line tower installation (land clearing).	• Minimal concern for a patchwork of small “footprints” along the right-of-way, in which vegetation will be cleared (including trees to be compensated), with a risk of some very localized slope instability. • Some loss of access to farm land (pasture and dryland crops), but temporary and compensated, as access will then be allowed after installation of towers. • Loss of visual aesthetics (the transmission towers against a pristine hill/mountain setting). • Some minor loss of terrestrial habitat for wildlife; wildlife movements will likely occur again, but away from the towers, and in altered vegetative habitat.
Operation	
16. Reduced worker numbers (just permanent staff).	• Diminishing local supplier business and reduced demand for informal businesses near construction sites and the highway. • Reduced risk of friction between immigrant workers and local communities; increased social/cultural stability.
17. Reservoir operation (flooded area).	• Permanent flooding of the margin of the National Park (right bank; steep slope vegetation) and degraded forest on the left bank (but a very small percentage of similar adjacent habitat on both sides of the river). • Alteration of upstream hydrology (from fast-flowing to more quiescent); this is a positive opportunity for aquatic habitat diversity and introduction of other trout species (upstream); option for the National Park to provide recreation and interpretation facilities; a positive for visual aesthetics (waterbody in mountain area); risk of safety issues, with increased public access to reservoir/river area. • Upstream areas (watershed) will need to be maintained to ensure good water

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
	quality.
18. Water intake to headrace.	• Risk of fish (brown trout) intake, due to accelerated velocity near intake; but a sequential screen apparatus can preclude this risk.
19. Diversion dam operation.	• Localized fish movement (brown trout) will be disrupted (no upstream movement, and just downstream movement through the spillway, with minimum environmental flow; however, no long-distant migrants use this part of the river. • Reduced downstream discharge, potential alteration of downstream surface water quality. • The dam itself and the reduced river flow will present a negative visual aesthetic, but in fact the dam site is not very accessible and not even visible from the highway.
20. Maintenance of minimum environment-al flow.	• Related to the above (#19), reduced downstream discharge, especially in the lean season (December-March); e-flow will be set at about 10% of lean season average discharge (approximately 0.554 m^3/s), which will be augmented increasingly downstream by perennial tributaries. • Alteration of river width for habitat (narrower); increasingly, discharge will be made up, downstream, by perennial and seasonal tributaries; monsoon flows will still be substantial; habitat for fish will still be maintained up to the diversion dam. • Possible reduced aquifer linkages between the Nikachhu and aquifers, but these will be maintained by the tributaries. • Reduced visual aesthetics of the downstream Nikachhu (smaller river), but, as above, it is not easily viewed from the highway or the inhabited areas to the east.
21. Occasional sediment purging.	• Purging of the desilting chambers may result in occasional turbidity pulses in downstream parts of the river, depending on how this process is undertaken; this will be a very transient effect, that can be mitigated by undertaking this during the monsoon, when turbidity in the river is at a maximum, in any case. • Temporary degradation of aquatic habitat and impacts on fish will be minimal, if undertaken at a time when the river has high suspended sediment loads (June-September); sediments will be flushed quickly, into the Mangdechhu and then further downstream.
22. Risk of dam burst.	• Explained in Section 5.2.4 of the report. • This is a very low probability event, that can be monitored, if there are signs of pending dam failure; the concern is for human safety, but in fact there are no communities within the flash flood zone downstream, due to the very steep topography adjacent to the Nikachhu for its distance to the Mangdechhu, and a high volume flood would be contained mostly in the gorge down to the

Summary Analysis of Impacts by Project Activity	
Project Activities	**Possible Impacts (on all baseline parameters)**
	confluence. • A warning system can nevertheless be installed to notify of a pending dam failure. • A flash flood would cause scour along the river banks and a huge turbidity plume, clogged with scrub vegetation and trees; it would also damage the existing downstream aquatic habitat and flush fish into the Mangdechhu; recovery from a flash flood would take a few years, but it would occur.
23. Maintaining cleared right-of-way for transmission line.	• Regular clearing of the vegetation within the right-of-way, especially near the tower foundations, will maintain stunted vegetation and reduce the quality of wildlife habitat; however, areas between the tower foundations can be allowed to grow to a height of about two meters, which will provide cover for most wildlife that need to move through the right-of-way. • Local communities will likely use most of the right-of-way for farming and pasture, as it will be more accessible and suitable than before installation of the transmission line. • Negative visual aesthetics of the transmission line will persist, with regular clearing of the right-of-way.

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
Physical	
Slope/ Sediment Stability	• The main concern is with road cuts (for the access roads), and muck disposal; these operations will require slope stabilization prior to and during work; therefore, the risk of sediments going down slope, knocking down trees and entering watercourses can be managed. With the exception of the dam site, and Adits 1 and 2, most of these works will be at least 500 meters from any rivers. • There are smaller risks from blasting, the quarry operation, and installation of the transmission tower foundations. • All new sediment slopes will eventually re-vegetate; this can be accelerated by planting appropriate steep slope vegetation as soon as possible after the slope has been created, and terracing as much as possible.
Climate	• The project will not impact climate *per se*; future climate variation may have an impact on annual rainfall amounts and seasonal patterns, which may affect the project power production modeling (the indication is an increase in rainfall and river discharge). • In the case of the Nikachhu Project, the concerns of possible Green House Gas

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
	(GHG) emissions from the reservoir due to biological decomposition of plants and other organic matters is negligiable in view of following reasons: o The volume of the reservoir and its spread is very small. o As is done in other hydropower projects, the reservoir area up to the full reservoir level shall cleared of all trees and vegetation before impoundment. The right bank of the reservoir is steep with minimum vegetation cover. o The dam will be provided with three 7 m (W) x 11 m (H) low level orifice sluice spillways operated by radial gates and one 7 m (W) x 8.50 m (H) high level overflow spillway. The low level gates will be operated in the monsoon season to remove sediment and settled debris from the reservoir, while the high level gate will be operated to safely remove floating debris. Moreover, the dam site is located at an elevation of 2,262 masl. o In view of the small storage volume and reservoir length, the removal of sediments and debris including vegetation brought in by floods will be effective. The effectiveness of reservoir flushing will also be studied through a physical hydraulic model during the pre-construction stage.
Air Quality	• All air quality impacts will be localized and transient during pre-construction and construction; these can all be mitigated with exhaust and dust controls. Local communities will not be adjacent to work sites. Workers can wear masks to reduce health impacts of dust. • Air quality over time could improve, if there is less burning of fuelwood and hydrocarbons for heat and cooking (replaced by electricity).
Noise Levels	• Noise increases will also be localized and transient during pre-construction and construction; noise increases can be managed with exhaust controls and workers wearing ear protection. Local communities will not be adjacent to work sites; however, distances to individual houses which may be near work sites are still to be surveyed; compensation may be required if houses are within 50 m.
Hydrology	• The main impact, of course, is a reduction in downstream river discharge, as a result of the diversion dam; a minimum environmental flow of at least 10% of lean season discharge, increasing to more than 15% between the dam and the confluence with the Mangdechhu (from perennial and seasonal tributaries), will compensate. • The “knock-on” effects of reduced downstream discharge include reduced river width below the dam, altered aquatic habitat, and less volume of habitat for brown trout. • A dam burst would create a sudden change in downstream hydrology (flash flood, with rapid dissipation downstream).
Groundwater	• Linkages between the project and groundwater are difficult to predict, but are

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
	expected to be minimal; a fuel spill could possibly contaminate groundwater, and blasting could create a localized shift in aquifer characteristics that might affect percolation and recharge, as well as springs. • Reduced discharge in the downstream of the Nikachhu could reduce aquifer recharge, that may be occurring as a normal linkage between the river and the aquifer. • Given the relatively high rainfall amounts in this area, and the many tributaries coming from heavily forested watersheds, any groundwater effects would likely not be measurable. • Water abstraction by the project construction activities will be limited to surface water supplies, as noted previously. • There are no wells in and near the project area, so tunneling is not expected to disrupt public groundwater access.
Surface Water Quality	• Transient reductions in surface water quality, caused by pre-construction and construction activities (would most likely be sediment intrusions into the river), should be of little concern, as they will very quickly be flushed downstream during most months (April-November); turbidity plumes created in the lean season will take longer to flush out. Work site management, and sediment controls in particular, will reduce most risks of this nature. • Bunded fuel storage, sewage treatment on-site, and proper management of worker camps should minimize the risk of contamination of surface water by organic and hazardous materials. • Operation of the dam will create a flooded area, which, while constantly circulating and exchanging (due to inflow to the headrace), could lead to some risk of reduced water quality; upper watershed management will be encouraged (this area will remain heavily forested, in any case, so sediment inputs to the reservoir should be minimal). • Occasional sediment purging from the desilting chambers could cause some turbidity plumes downstream, but this will likely be done during the high discharge monsoon season, when the river is already carrying a higher sediment load, and discharge volumes are quite high, which will accelerate flushing. • Reduced discharges in the lean season (with minimum environmental flow) create a higher risk of reduced water quality in downstream areas.
Biological	
Biodiversity	• Land acquisition and related clearing (mostly in degraded forest areas, for the dam and powerhouse components, and the transmission line) will reduce available habitat (vegetation) and may therefore reduce available area for wildlife. With the exception of temporary construction activity in about 15% of the

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
	width of the biological corridor (which is critical habitat), and a very small permanent take of steep rock slope on the edge of the Park (which is also critical habitat; see below), none of these project sites are critical or unique in terms of biodiversity, and no vulnerable or endangered species are expected to be affected to the point of population reduction. • Given the extremely small percentage of the habitat/biodiversity complex that exists in the Trongsa area and in adjacent areas that may be taken over by the project (less than 1% of the roaming range of most species), no net loss of species, or incremental pressure on specific species, is expected to occur.
Protected Areas/ Biological Corridors	• The dam site construction activity and the flooded area above the diversion dam will impinge on the buffer zone of the Jigme Signye Wangchuck National Park (which is critical habitat), but in an inaccessible, steep slope area that does not support extensive forest cover or wildlife access; this area of impingement represents 0.0014% of the total area of the Park (0.024 km^2 of submergence to the park's total area of 1,723 km^2). • The "pond" above the diversion dam can be made a Park interpretation feature (or limited recreation area; fish stock area), which is potentially positive. • Construction activity at Adit 2 in the Biological Corridor (which is critical habitat) will be temporary (over about 1.5 - 2 years), and represents only 12-15% of the width of the eastern corridor (there are three connecting JSWNP), or about 5% of the width of these three corridors. • The eastern corridor is already crossed completely by the National Highway. • Temporary project activity in the eastern corridor is not expected to disrupt wildlife movements, most of which occur at night, when construction activity will be minimized.
Vegetative Cover/ Diversity	• All land clearing will occur on the north side of the Nikachhu, where forests have been degrading over the last 30-40 years (it is not protected *per se*), with intrusions for pasture and dryland cultivation, as well as wood extraction; no unique habitats or protected/ vulnerable species will be cleared, as the cleared area is a very small percentage of similar vegetation and habitat all along the National Highway in this area. • While some cleared areas will remain permanently converted to project sites, they will be enhanced with plantings, and all temporarily cleared areas will be allowed to revert to natural vegetative cover, or will be planted with specific species.
Forest Resources	• As noted above, no vulnerable or protected tree species will be cut. • All trees that will be cut will be compensated for, by replanting appropriate species in an area 2x the size of the project cleared areas; much of the cut wood

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
	can be used for fuel.
Wildlife, Terrestrial, Avian	• The National Park and biological corridor are deemed to be critical habitat; however, the temporary occlusion of part of the biological corridor (which is degraded forest and already crossed in total by the National Highway) and permanent flooding of a very small fraction of steep slope on the edge of the Park (which is not easily accessed by larger wildlife) significantly reduce concerns about project impingement on critical habitat, As such, it is expected that there are no specific unique wildlife habitats in these two project footprints (and the surrounding area, mostly in the park to the south, provides a huge contiguity of critical habitat that will remain undisturbed). The project will not create any large barriers to wildlife and bird movements; any disruption of wildlife behaviour will be temporary (just during pre-construction and construction), and animals (including birds) will be able to move around or over construction sites. • Wildlife are at risk from poaching (construction workers), but this potential activity will be disseminated as an illegal activity and monitored.
Aquatic Habitats	• Aquatic habitat is at risk from sediment and hazardous material inputs, if work site management and mitigation measures are not properly designed and implemented; the most pervasive risk is sediments entering the watercourses. • Fortunately, the creeks, tributaries, and the Nikachhu are currently fast-flowing (in most months), and any sediment inputs will likely flush out quite quickly (in most months, except during the lean season); any intrusion or contamination of aquatic habitat during the pre-construction and construction phases would be transient. • Formation of the reservoir above the diversion dam will be a positive feature (diversity of aquatic habitats), whereas reduction in discharge below the diversion dam (minimum environmental flow) will reduce the volume of river habitat, but not necessarily the quality of that habitat; volume is made up over the distance between the dam and the confluence with the Mangdechhu by seasonal and perennial tributaries. • During project operation, there will be occasional turbidity pulses in the Nikachhu, due to cleaning of the desilting chambers, but this will occur during the monsoon, when river discharge is high and suspended sediment levels are at their annual peak, in any case. • A dam burst would cause a rapid scouring effect in the downstream of the Nikachhu, which would create a significant alteration of existing aquatic habitat; this would require several years for recovery.
Fish Stocks/ Migration	• During pre-construction and construction, fish (specifically brown trout) will continue to have access to the Nikachhu, with unrestricted movements (going

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
	through the diversion tunnel). • They may be at risk from poaching and from sediment and hazardous material spills into the river. • During project operation, fish will continue to be able to make movements downstream (they will be screened from the headrace intake, going through the spillway); they will not be able to move upstream past the diversion dam, but, in any case, brown trout do not make long migrations in the Nikachhu, due to the series of waterfalls between the dam site and the confluence with the Mangdechhu, and do not appear to be present in the lower reach of the Nikachhu and in the Mangdechhu. • The reservoir above the diversion dam will provide a positive opportunity for fish stocking (perhaps snow trout can be introduced; these may start to compete effectively with brown trout).
Socio-Economic	
Use of Farm Land	• Temporary and permanent land acquisition for the project will result in loss of access to farm land (mostly in the eastern section of the project area and along parts of the transmission line alignment); this will be compensated. • After construction and after installation of the transmission line, most areas will be accessible again for pasture and/or dryland cultivation.
Aesthetics	• The main negative impact on visual aesthetics in the project area will occur during construction, as a result of clearing, site work, and heavy equipment and vehicles on the road; this will obviously stop when the project construction is finished. • Persistent negative visual impacts will be minimal, as the temporary project sites will revert to vegetative cover, and permanent sites will be planted with suitable vegetation; the dam and other infrastructure, as well as the reduced size of the Nikachhu downstream (all negative for visual aesthetics) will fortunately not be very visible from the highway or inhabited areas. • The reservoir above the diversion dam will be a positive visual feature, and will have some potential for Park interpretation and recreation, depending on how the Park allows public access to this area. • No physical cultural sites will be affected (the nearest cultural site is at Chendibji Chorten, 6 km from the dam site).
Business/ Employment	• The project will create opportunities for employment and supplier business, for the duration of the project construction; however, their sustainability (jobs and businesses) will be at risk when the project construction is complete; this risk needs to be disseminated and understood by the local community, as future infrastructure development in the area, and related opportunities, remain unclear.

Summary Analysis of Impacts by Baseline Parameter	
Parameter	**Accumulated Impacts From all Project Activities**
Services	• Improvement of parts of the National Highway, and creation of some access roads near local communities, will facilitate local transportation; the project will also increase access to electricity.
Social/ Cultural Stability	• There is some risk of social and cultural instability, as up to 2,000 workers will be involved with the project, and many of these will be coming from outside the region (possibly India); while Bhutan is increasingly familiar and comfortable with worker influxes, the risk still remains that local communities may not easily accommodate their presence in the area, especially if they engage in illegal activities.
Health/ Safety	• The main health and safety risks are associated with construction activities, and the risks are faced by workers; they will be briefed on risks and issued with PPE. • Local communities may also face some risk in using the National Highway and local access roads, when construction equipment (heavy equipment and vehicles) are operating on the roads. • Access to the reservoir may be a public safety concern; secure fencing is proposed; the option for public access to some part of the reservoir and provision of National Park interpretation needs careful study. • A dam burst could present a risk to public safety, but it is expected that no communities will be within the flash flood zone, in the event of a dam burst; a warning system will, nevertheless, be installed and disseminated, in case people are on or near the downstream section of the Nikachhu at the time of pending dam failure.

6.3 Expected Impacts and Required Mitigation Measures

In this section, the significance of predicted impacts (identified in Section 6.2) is assessed, which then informs the nature of required mitigation measures. Because mitigation is tied to project activities, the impact assessment is also aligned in this way, so that activities and locations can be managed in a holistic manner, and contract covenants for specific contractors properly tied to their actions. Since many of the assessments of impacts are based on the existing quality of the receiving environment and the ratio of impacted areas to undisturbed areas (within the immediate vicinity), visual ratio analysis is used, where needed, to make the case for relatively low levels of concern for most impacts. Note that the assessment suggests that there are no significant negative environmental and socio-economic impacts that cannot be mitigated, so the project should be able to proceed without such concerns. The original examination of alternative sites was able to filter out sites that might have created concerns about environmental and socio-economic issues.

Figure 6-1 shows the ratio analysis figure that is used to provide a scale for the various possible impacts on land use, habitats, and biological resources in particular. In general (based on a combination of scientific assessment and subjective judgment), any accumulated area impacted by the project that makes up less than 1% of the map area is not expected to create any persistent negative impacts. This assumes that the remaining 99% is sufficient to support local communities and wildlife that occur in the area, and that wildlife do not have any barriers to accessing those continguous areas; some of which are much better than the cleared areas (for example, all parts of JSWNP), and some of which may be in worse condition than the project cleared areas (for example, areas along the road and cultivated land). The map area, which is about 13 x 15 km, is considered to be "local habitat": this means an area that is within the travel distance and familiarity of local communities and the movement range of larger wildlife and birds. It also includes the combination of land inhabited by local communities, the undisturbed forest (the National Park), and the degraded forest north of the Nikachhu (creating a non-uniform habitat, as noted above). This map area therefore includes the immediate project area and the extended area that is expected to include the "zone of influence" of the project.

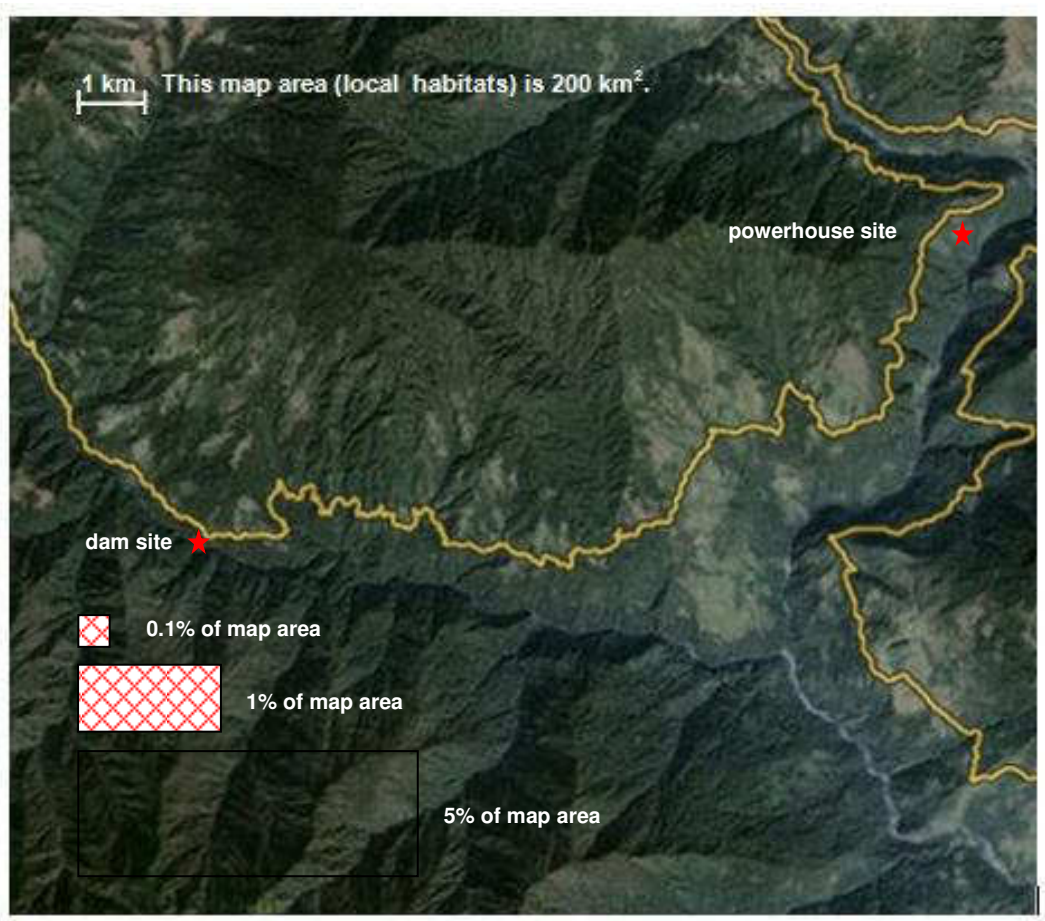


Figure 6-1: Example of ratio analysis that is used to provide scale to possible impacts (examples of 0.1%, 1% and 5% of the map area are shown to indicate scale).

6.3.1 Pre-Construction Phase

6.3.1.1 Land Acquisition

There will be two kinds of land acquisition, which have consequences for the extent and duration of environmental and social impacts. In the case of temporary land acquisition (3-4 years at most), which includes muck disposal, the batching plant, and the construction and labour camps, all this land will be rehabilitated and allowed to re-vegetate and become available again to the local communities and wildlife. Access roads may also revert to a wild state, although given that they will lead from the National Highway to terraced and re-vegetated muck disposal areas, they may retain their usefulness, and provide access to these new areas, which would have value for farming (either dryland cultivation, or animal grazing; a significant positive impact). Project Component which might create an almost permanent land type change, includes the dam site, the powerhouse site, the staff quarters and the transmission line alignment however, the muck disposal areas and the construction and labour camps will revert back to secondary forest, scrub vegetation, or pasture immediately after project construction are therefore considered as temporary. The total project land requirement is only 0.64%, with most in degraded forest, of the land area of Tangsibji Geog. The detail of project land acquisition is shown in Figure 6-2 and the nature of the land to be taken up is shown in Figure 6-3.

A total of about 254 acres (101.6 ha) shall be acquired by the project of which approximately 208 acres (83.2 ha) shall be temporary and the permanent land acquisition is equivalent to 46 acres (18.4 ha). Of course, the real impacts associated with land acquisition are not related to ownership *per se*, but are due to land clearing and the actual alteration of land type. Given the fact that both types of project land acquisition are less than 1% of the map area, and that temporary land acquisition will actually result in rehabilitated, re-vegetated, and possibly more useful land for local communities (the access roads and level terraced areas), the net impacts of temporary and permanent project land acquisition are deemed to be acceptable.

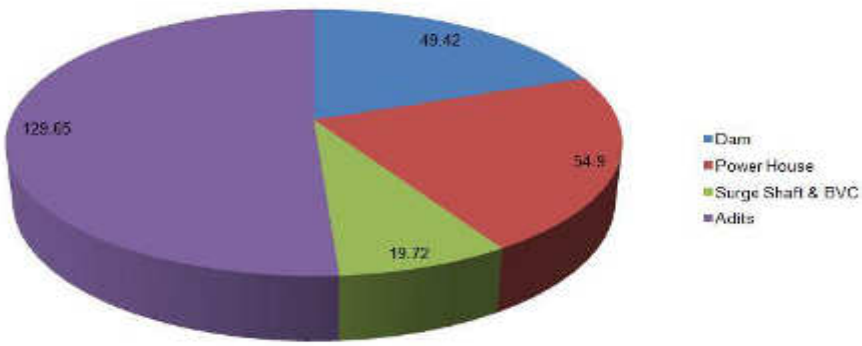


Figure 6-2: Land requirements of various project components (in acres).

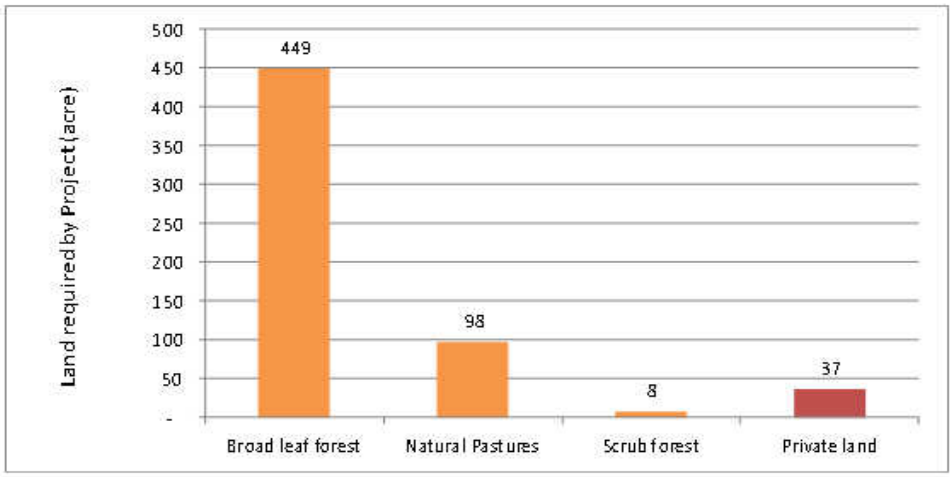


Figure 6-3: Land types in the project acquisition area (private land requirement is now estimated at only 3.577 acres, or 1.43 ha, as of April 2014).

Figure 6-4: Ratio of project land acquisition to the map area.

The direct impact of project land acquisition (temporary and permanent) is the requirement to compensate for loss of land (permanent) and temporary loss of access to land. As noted in Figure 6-3, 37 acres of land (about 15 hectares, or 0.15 km^2) is privately owned (note that the recently completed social survey has confirmed that the actual project requirement for private land is now much less; 3.577 acres, or 1.43 ha, with attendant reduced impacts). Eleven entities, (includingten households and one institution) will be affected by the project (household details and compensation arrangements are provided in Part 3). Table 6-3 provides an overview of affected land at various locations. The socio-economic assessment revealed that none of the affected households are below the poverty line (and therefore more vulnerable) and only one household owns less than one acre of land. The affected households draw 63% of their income from farming. Most of the families (over 80%) own double-storied houses and many possess amenities, such as TVs. This all suggests that proper compensation (as already worked out) will prevent any additional vulnerabilities for the affected households.

Table 6-3: Project affected land (dam and powerhouse components) at various locations.

No.	Component	Description	Area (Acre)	GRFL	Total SRFL (Acre)	Locations
1	Dam	Residential Complex	1.5	1.5	46.433	Nyala
		Non-Residential Complex	2.85	2.85		
		Reservoir Area	12.29	12.29		
		Contractor Facility and Establishment	8.15	8.15		
		Batching Plant and Crushing Plant	6.93	6.93		
		Muck Disposal	10.76	10.76		
		Access Road	4.54	3.953		
2	Power House	Residential Complex	1.5	1.5	54.063	Norbuodi
		Non-Residential Complex	2.63	2.63		
		Contractor Facility and Establishment	16.6	16.6		
		Muck Disposal	17.55	17.55		
		Access Road	18.14	15.783		
3	Surge Shaft	Non-Residential Complex	0.91	0.91	18.01	Norbuodi Top
		Contractor Facility and Establishment	3	3		

No.	Component	Description	Area (Acre)	GRFL	Total SRFL (Acre)	Locations
		Muck Disposal	10.18	10.18		
		Access Road	4.13	3.92		
4	HRT and ADITs					
	ADIT - 1	Contractor Facility and Establishment	0.9	0.9	19.95	Alu Bari
		Muck Disposal	13.82	13.82		
		Access Road	5.23	5.23		
	ADIT - 2	Contractor Facility and Establishment	2.5	2.5	24.99	Zaapla
		Muck Disposal	18.04	18.04		
		Access Road	4.45	4.45		
	ADIT - 3	Contractor Facility and Establishment	6.5	6.5	31.787	Near Tsheringma Drupchhu
		Muck Disposal	20.55	20.55		
		Access Road	5.16	4.737		
	ADIT - 4	Contractor Facility and Establishment	2.5	2.5	12.14	Tsangkha
		Muck Disposal	8.14	8.14		
		Access Road	1.5	1.5		
	ADIT - 5	Contractor Facility and Establishment	2.5	2.5	18.62	Norbuodi
		Muck Disposal	15.33	15.33		
		Access Road	0.79	0.79		
5	ADIT to Pressure Shaft	Muck Disposal	4.1	4.1	5.21	Norbuodi
		Access Road	1.11	1.11		
6	33 kV Distribution Line for Construction Power		59.3	59.3	59.3	
7	132 kV Transmission line for power evacuation		0.6			Refe, Kinga Rabten & Yurmung
Total Area (Acres)			**294.68**		**290.503**	

Only 6 towers will occur on private land. Required compensation can then be established, in the same manner as has been done for all the other project components and has accordingly been addressed in Resettlement Plan (Part 3).

Mitigation: As noted previously, most of the impacts associated with project land acquisition pertain to actual activity and land use, which are discussed below. Mitigation for land acquisition is therefore restricted to compensation for temporary and permanent land acquisition and maintenance of positive visual aesthetics on land that is acquired for the project. Compensation in Bhutan is guided by the principle that no household should be worse off compared to their existing living conditions. Land compensation is therefore guided by the "Land Compensation Rates (2009)" and the Land Act of Bhutan (2007). The compensation rates also apply for compensating structures and fruit trees. There are three classes of land under the rural category, based on

distance from the municipal boundary. As the Nikachhu HPP falls within Class C of rural land, the compensation rate per decimal (= 40.47 m^2) is Nu 2,262.54, which means one acre will cost Nu 226,254. As the land acquisition will be governed by the Land Act 2007, Chapter 7 specifically pertains to land that will be acquired by the Government for wider public interest. It states that acquisition shall entail fair compensation. The compensation can be in cash or land or a combination of both (the land owner shall have the discretion to opt for one or the other). All the compensation process will be completed before the actual start of the project on the ground. If land is provided as compensation, the certificate for new land will be made available so that the affected people do not encounter any problems in the future. No land will be occupied by the project until the compensation process is completed and the affected are fully compensated.

If affected households are not satisfied with the proposed compensation, the grievance redress mechanism, based on the existing governance structure involving the Geog Yargay Tshogchung and the Dzongkhag Yargay Tshogde can be activated (all such details are provided in the Resettlement Plan, Part 3 of the ESIA Report; a summary is provided in the EMP, Part 2). Note that acquisition of land from the affected households will preclude most concerns about proximity to construction noise and dust. The social survey determined that there are no households in close proximity of less than 50 meters of the project activities.

In addition to these standard measures, the project will be able to provide job opportunities (one job per family can be given, during the construction period, to those affected adversely as per Sustainable Hydropower Development Policy 2008, depending on their skills). The project can also rent local houses, if suitable. Furthermore, to reduce disturbance to existing infrastructure, the opportunities for alignment of project roads with existing roads have been examined, and several possibilities have been taken advantage of; for example: aligning the road to Adit 3 with the existing Tansgibji farm road to the extent possible; the road to Adit 5 with the existing quarry road; and, the road to the muck disposal site at Tsangkha with the existing power tiller track.

As noted previously, permanent land acquisition could result in negative visual aesthetics, so every effort will be made to have the structures on permanent project sites fit into the local architecture and landscape (as DGPC has done with such structures at the Dagachhu project site), and all open areas and access roads will be planted with native flowering shrubs and ornamental trees to improve the visual appeal and acceptability of the permanent project sites (as has been done with the Dagachhu project). In any case, most of the permanent sites will not even be visible from the National Highway or inhabited areas, so the project will have very little visual presence in the landscape.

Land that is used temporarily for project construction will revert back to the Government or the community (depending on its original status). Work sites, the muck disposal areas (fully

rehabilitated as terraced vegetated fields), and the access roads can either be used by the local communities, or allowed to revegetate naturally, depending on the community wishes. Ongoing discussions with the local government and communities will define the specific fate of each of these temporary project land use areas. This will also help to define the specific needs for a closure plan (whether sites remain usable, are revegetated and rehabilitated, or are allowed to revert to wild state). As such, as specific closure plan for construction works and facilities can only be developed after the exact project "footprints" have been defined by DGPC and the individual contractors; the fate of every site will then be discussed with the local communities, to ensure maximum benefit of those sites being provided to the communities, or rehabilitation to natural state, if that is the desire of the local community and Government agencies will allow it.

In addition to the process noted above, the communities that are currently relying on the micro-hydel (Tangsibji and Chendebji) will be connected to the electricity grid, which will ensure a stable electricity supply year-round (currently not the case for these communities).

6.3.1.2 Land Clearing and Cuts (Works Sites and Access Roads)

There are several key steps in land clearing (both unavoidable) that can cause negative impacts and which require mitigation, including:

- removal of trees and undergrowth (creating a loss of habitat for wildlife; mostly a concern within the biological corridor, although this area will rapidly re-vegetate); and,
- cutting into the land to create road bases and level areas for construction (mobilizing sediments and creating the risk of slope instability, potential occlusion of creeks and rivers, and temporary decrease in water quality).

As noted previously, this activity will occur within a total of 254 acres (101.6 ha) within the project area, and only about half of this will result in a permanent change in natural vegetative cover. Land that is temporarily cleared will be allowed to revegetate (subject to comments in the previous section) and can be enhanced in this process with replanting of appropriate tree species (in an area that is twice the size of the area cleared, according to current guidelines in Bhutan). The significance of these impacts is discussed below.

With regard to trees, the impact has been assessed based on both the volume of trees that would be lost and the number of trees (this is standard practice for projects of this nature in Bhutan). The required data to support the impact and mitigation analysis for trees were collected during the field surveys; this involved calculating the density of trees per unit area, and noting the trees above 50 cm in girth (to calculate total volume). The project "footprints" were then overlain with GIS on the tree survey data. The estimated maximum number of trees that would be cut for the project sites is 153,688 (Figure 6-5 shows the number of trees that would be cut for each project component; in

fact, the recent field survey for the transmission line alignment indicated a maximum of 15,066 trees might need cutting; it would probably be less than this due to the cables spanning valleys where trees would not need to be cut). The estimated volume of trees that would be cut is 398,709 m^3 (mostly suitable for firewood). Figure 6-6 shows the volume of trees to be cut for each project component. In the process of clearing vegetation, no endangered or endemic tree species would be lost, and most sites would almost immediately start to consolidate with groundcover vegetation, which would help prevent erosion. While cutting trees for the project would result in some loss of a carbon sink in the area (the loss is estimated at about 1.2% to 1.5% of the available vegetation in the project area), half of the cleared sites will be allowed to re-vegetate, and the carbon dioxide offset provided by renewable energy from the Nikachhu project greatly exceeds the loss of the carbon sink and the possible burning of the firewood (see Section 3.5).

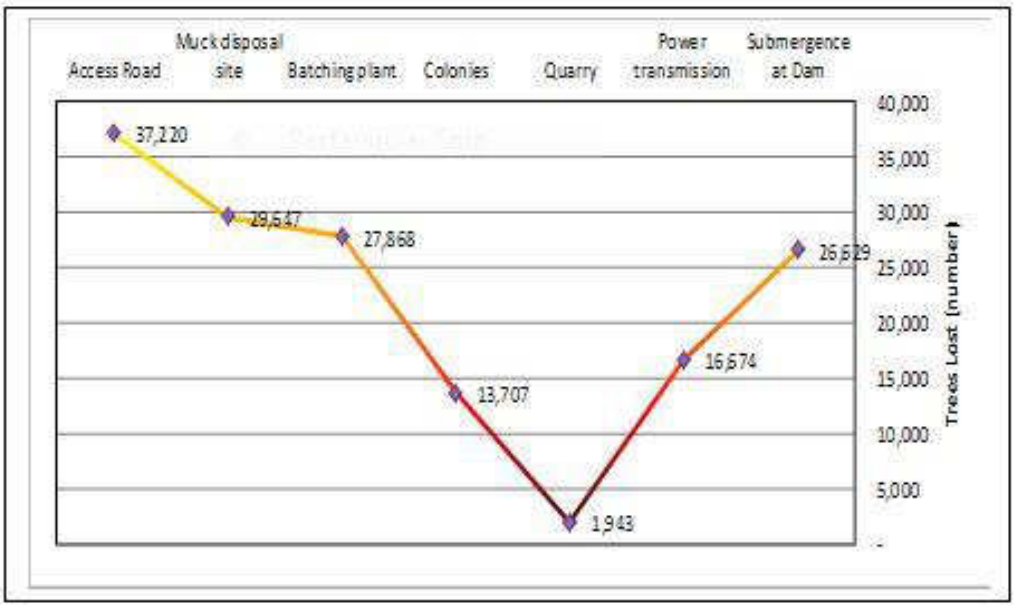


Figure 6-5: Estimated number of trees requiring clearing for various project components.

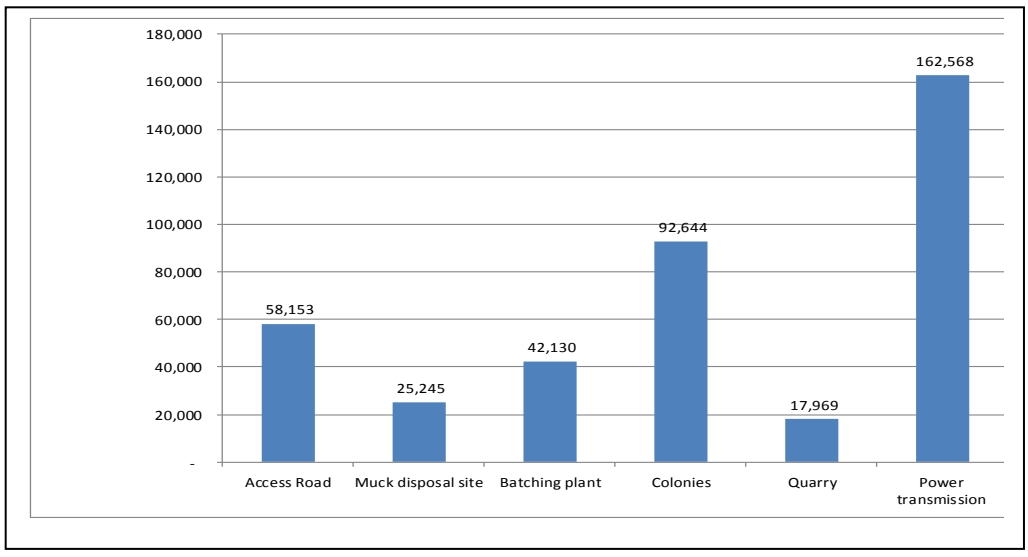


Figure 6-6: Estimated volume (m^3) of trees that would be cleared.

The only land clearing that will be required in the easternmost biological corridor connecting JSWNP and northern areas will be associated with Adit 2, which will require about 1.5 - 2 years of activity, after which the access road and muck disposal site will be rehabilitated and allowed to re-vegetate. The cleared area represents only 12-15% of the width of the eastern corridor, or about 5% of the width of the three corridors, which leaves 95% of the width of the three corridors completely undisturbed. The eastern corridor is already crossed by the National Highway. The potential impact of temporary land clearing within the eastern corridor is therefore expected to be negligible, and certainly much less than the ongoing permanent effect of the National Highway. However, since temporary and permanent land acquisition and land clearing will impinge on critical habitat (a permanent small sliver of the Park buffer zone at the dam site and a temporary spot in the biological corridor, as noted above), critical habitat tests are required. Note that some animals listed for the whole of the National Park (although exact locations are not specified) are IUCN status or Bhutan Schedule 1 animals. If they are not known to occur in the vicinity of the project footprints, they are not listed below (see Table 5-16 for a list of all IUCN status and Bhutan Schedule 1 mammals, and whether or not they occur at the project site; status birds and vegetation are described in their respective sections). The results of the critical habitat tests are summarized below:

Question	Answer
1. Is the site legally protected or proposed for protection?	Yes, a very small part of the Jigme Singye Wangchuk National Park buffer zone (0.0014% of the Park area; a steep rock slope) will be flooded, and there will be temporary construction works in 0.0047% (in terms of area) of the total Biological Corridor strip that connects northern areas of Bhutan to the Park.
2. Are the project activities consistent with the protected area management plan?	Yes, as the Park allows some activities and habitation within the buffer zone, and Biological Corridors have less restrictive management measures that allow clearances for temporary works. The JSWNP does not as yet have a full Management Plan (the project is budgeting for various Park activities that will inform development of a plan). Clearances have been issued for project work in both locations.
3. Have the protected area sponsors and managers, local communities and other key stakeholders been consulted and their views taken into account?	Yes, there have been at least three consultations with all relevant stakeholders and clearances and non-objection certificates have been obtained. All concerns expressed to date have been addressed in proposed EMP measures.
4. Have appropriate additional programs been implemented to promote and enhance the conservation aims of the protected area?	Yes, the EMP will provide significant funding for habitat replacement and wildlife conservation and monitoring measures, as well as institutional strengthening and logistics support for the JSWNP.
5. Will the project reduce populations of any globally or nationally recognized critically endangered or endangered species? Globally or nationally recognized (Bhutan Schedule 1)	No, because all the species noted to the left have significant wider distribution in Bhutan. All the mammals will have uninhibited “go-around” room (at least 1-2 km in thick forest) that will allow full

Question	Answer
critically endangered or endangered species present in project area are: Tiger Leopard Leopard Cat Red Panda Dhole (wild dog) Golden Langur Gaur Serow Asiatic (Himalayan) Black Bear Tree fern (*Cyathea spinulosa*)	contiguity of populations in the project area. Furthermore, the temporary work area in the Biological Corridor will be allowed to fully re-vegetate after 1.5-2 years of construction work, allowing the Biological Corridor to become fully intact again. Finally, the very small part of the JSWNP that will be flooded is currently a steep rock slope that cannot be accessed by wildlife. The tree fern *Cyathea spinulosa* occurs throughout Bhutan, Nepal, India, China, and Taiwan.
6. Will there be measurable adverse impacts, or likelihood of such, on the habitat's ability to support its high value species and functions?	No, as noted above, all animals will continue to have full access to very large areas of contiguous habitat that will remain under protection (mostly in the JSWNP).
7. Will there be a loss in habitat which will compromise the persistence of a viable and representative host ecosystem?	No, the project footprint is less than 0.01% of the available protected habitat of the same type (mostly the forest area in JSWNP).
Mitigation measures are defined in the EMP for the residual impacts and EMP implementation will be monitored.	

The main concern with land clearing and making cuts into mountain slopes is associated with the muck disposal sites and developing the access roads. The latter are required at ten locations, with an accumulated total length of 16.488 km (see Figure 6-7). These roads typically require a corridor of 30 m (Road Act Bhutan, 2004). While the access roads for the dam site, Adit 1, and Adit 3 will be developed on relatively moderate slopes (average terrain gradient of 40%, therefore with less concern for land slides), the access roads for Adit 4, the surge shaft, and the powerhouse area will be constructed in areas with average terrain gradients above 56% (some as high as 80%), which is very steep by any standard, and increases the risk of slope instability and loss of surficial sediments. Luckily, where the slopes are greatest, and the risk of slope instability and soil loss is highest, the locations are further away from the Nikachhu (however, closer to the Mangdechhu), so possible occlusion of watercourses by sediments lost down-slope and resultant temporary degradation of water quality and aquatic habitat is diminished as a risk. With regard to the Mangdechhu, this river is wider than the Nikachhu, and with a higher discharge rate, would flush sediments that go into the river rather quickly (this river, at this location, has already been subjected to the works related to the Mangdechhu dam). While slope instability, loss of sediments downslope and possible associated negative effects on water quality and aquatic habitat might occur, the effects are expected to be temporary (given fairly high flushing rates) and these risks can be mitigated, in any case, as discussed below.

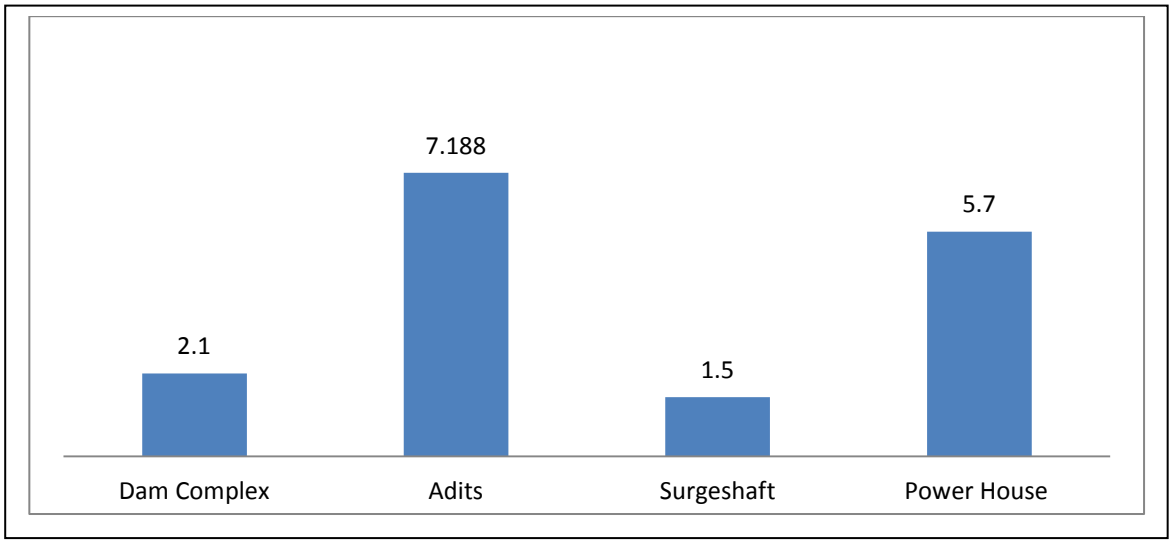


Figure 6-7: Access roads (km) required to access each project component.

Mitigation: Mitigation is required to address tree clearing and risk of slope instability and sediment mobilization. Land clearing and temporary construction activity in the eastern biological corridor is not expected to need specific mitigation measures, except to allow re-vegetation as quickly as possible. However, tree cutting will be undertaken, as much as possible, in the dry season, before breeding of most animals, and before the monsoon, when tree cutting work could create additional damage and muddy run-off in the forest. The loss of trees will be addressed according to the current guidelines in Bhutan, with compensatory planting of trees in an area that is 2x the size of the area cleared, allowing for up to 40% damage or mortality; saplings will be monitored and replaced as needed, to ensure a high survival rate for the afforestation program (details are provided in the EMP. Tree planting will be undertaken on exposed ground in the project area, and on construction sites, when they are finished with, using appropriate tree species (to be determined in consultation with Department of Forests). There is a need to manage the tree cutting properly, even though the felled trees may only have value as firewood. Usually, the contractor requirements include proper cutting, extraction, and recording of wood as firewood (which can be used locally), and payments are made accordingly. It is important to establish payment rates that do not encourage the contractors to dump wood, or bury the trees. This rate can be worked out with the Department of Forest and Park Services.

In addition to planting trees in the project work areas as they are finished and ready for rehabilitation, other barren areas have been proposed for planting (proposed by the Dzongkhag Forest Officer, based on discussions with the Geog), as follows:

1. Drangla Community Forest (CF, 25 ha);

2. Nyala CF (25 ha);

3. Tangsibji CF (45 ha);

4. Tshangkha CF (30 ha);

5. kella Langbro CF (10 ha); and,

6. kella Cherub CF (15 ha).

There may also be some locations near Sephu that are suitable for replantation and this would help with upper catchment protection, along with plantations above Tshangkha, where there is recent forest fire damage. There is also a proposal to revive and enhance the the old route from Chendibji to Tangsibji, which would be suitable for walking, biking, and bird watching. Details on appropriate tree species and planting methods are provided in the EMP.

The greatest concern with land clearing and making road cuts is slope stabilization. The most practical safe approach is to plan for road formation cutting in dry seasons; this is from September to May in the project area, as experience in other areas indicates that road cutting in other months can increase the risk of slope instability and related environmental damage by three times. In order to accommodate all the road cutting work within a dry season, the road works can be made into three contract packages, to be undertaken simultaneously. Experience in other parts of Bhutan also suggests that excavators, rather than bulldozers, should be used, to reduce ground movement of surficial sediments. It will be important, at the takeoff point, to erect a retaining wall at the same time that formation cutting is going on, to prevent damage to the Highway from local slides. Steep exposed slopes should be protected with retaining walls, hopefully before significant sediment excavation and certainly before the onset of the monsoon. Simultaneous blasting using codex and detonating cord could be adopted to prevent flying rocks, thus keeping broken rocks in one place, and not going downslope. Special care will be taken to construct the access road to Adit 3 as there is the canal for the micro-hydroelectricity project located below the National Highway (this also serves as irrigation water for paddy cultivation for Tangsibji Geog).

Finally, there has been positive experience with the road project in southern Bhutan, in which loose slopes have been stabilized with the plantation of various local species (bioengineering approach). This will be attempted with the Nikachhu project as well. For all project work sites, site drainage will be carefully studied and managed, to prevent erosion of exposed sediments into adjacent watercourses. Piles of sediments will also be covered to prevent their erosion. The use of small checkdams and sediment retention ponds adjacent to cleared work sites will also be studied and implemented where necessary.

The first steps in land clearing (entry of workers and equipment) will flush out animals and significantly alter their habitats (they will be unable to retreat). Animals will be allowed to move

away from the work sites; any that cannot move, for whatever reason, will be trapped and then moved to appropriate adjacent habitats (an animal rescue plan). There will be provision in the mitigation plan for additional animal surveying by the JSWNP, to improve the understanding of wildlife presence, distribution, and seasonality in the vicinity of the Nikachhu project.

Although surveys have been done, with regard to cultural sites, and no monuments or structures have been found (and there are no records of such in the District Office), workers and site managers will be as vigilant as possible during land clearing, in case evidence of cultural sites is found. If this is the case, the District Office will be contacted and measures put in place to protect any such sites.

6.3.1.3 Influx of Workers (Worker Camps)

Workers for the Nikachhu project will come in two phases, during the pre-construction phase to undertake the land clearing and preparation of access roads (relatively small numbers) and during the construction phase, for all project components, when numbers may rise to about 2,000. Many of these will obviously come from outside the district. The main concerns with an influx of workers include: possible social instability (poor mingling of workers from outside the district, or from outside Bhutan, with local communities, although Bhutanese have increasing experience with worker influxes and seem to handle them with equanimity); pressure on housing, infrastructure, and services; risk of poaching (fish, birds, wildlife); risk of communicable diseases spreading in the local community, and, concerns about excess waste and sewage entering the local environment. Workers also face their own risks, with health concerns in the camps (communicable diseases, poor air quality), and safety issues at the work sites (these require strict work site codes and issuance of PPEs – personal protection equipment). On the other hand, the influx of workers and the project itself will create many business opportunities (local suppliers) and chances for employment. These are addressed below. Note that all can be well-managed and mitigated, as has been the experience with several other infrastructure development projects in Bhutan. It is also important to remember that when the project construction is completed, worker numbers will decrease significantly, just leaving permanent project staff, so all positive and negative impacts associated with an influx of workers will be transient.

With regard to housing, the carrying capacity of Trongsa Town has reached a point of visitor saturation, due to the Mangdechhu hydropower project, which is expected to be completed in 2017. Up until now, last-minute visitors have faced difficulty in finding accommodation (there are six hotels in the area). However, the Mangdechhu project has built its own accommodations, and with completion of construction work, the pressure on temporary visitor accommodation will be much reduced, perhaps just in time for the start of the worker influx for the Nikachhu project. Of course,

the high visitor numbers in the Trongsa area have been very positive for local business, and this will continue for the time being with the Nikachhu project. In any case, the Nikachhu project will build temporary and permanent accommodation for its workers, which will reduce the possible pressure on local housing stock and commercial accommodation.

The project itself and the influx of workers will add stress to the availability of essential fuel items (liquid petroleum gas (LPG), diesel, petrol, and kerosene). This was observed during the first phase of the Mangdechhu project construction, and the Government quota for the Trongsa area had to be raised (apparently shortages were still experienced). With this precedent set (adjusting quotas of subsidized fuels to meet unusual demand), it will obviously be an option for the Nikachhu project. On the other hand, the increased availability of electricity over the longer-term (from both Mangdechhu and Nikachhu) will potentially reduce some pressure on fuel (for heating and cooking). There may also be some benefit in the use of the cut trees (fuelwood quality) to help take pressure off LPG and kerosene; this is a positive side effect of having to cut the trees, in any case. Also, as the Mangdechhu project winds down, and consumption of subsidized fuels decreases somewhat, this will make room for the fuel demand associated with the Nikachhu project and the worker camp needs.

As noted above, project housing will be segregated into permanent and temporary types. The permanent acquisition is proposed for reservoir, colonies, access roads for about 46 acres (18.4 ha) which are mostly forest and pasture land, and the temporary acquisition for contractor establishment facility, muck disposal and access road to adits which covers about 208 acres (83.2 ha). Impacts related to the actual clearing of this land were discussed previously in Section 6.3.1.1 (the spatial ratio analysis, which suggests acceptability of permanent and temporary land conversion, each less than 1% of the project area). The main concern is the generation of waste and sewage at areas where workers are concentrated and live (the camps). Without proper waste separation and management, and proper sewage treatment (septic tanks and soak-aways, suitable for this location), solid waste and sewage could enter the adjacent forest area and the watercourses (the Nikachhu is only about 150 meters away from the proposed permanent colony). These will require good planning and effective management (discussed below under mitigation). The risk of poaching is quite real, and access to the National Park will have to be barred, and supported with dissemination about the illegality of poaching, as well as the risk of fines and job loss, if caught in these illegal activities.

Mitigation: As noted above, all concerns associated with a worker influx and development of the worker camps can be addressed with good planning and suitable mitigation measures; this has been done for other infrastructure development projects in Bhutan and appropriate experience and procedures are now in place (for example, Dagachhu hydropower project, and the road project in southern Bhutan, both of which were examined in detail during the preparation of this ESIA). The

main mitigation approach is proper siting and design of the temporary and permanent worker camps, and to get these built quickly (at least 100 single units have been suggested to avoid pressure on local housing and services) rather than relying on commercial enterprises in Trongsa District providing these (this is a good lesson from the Punatsangchhu and Mangdechhu projects). The relative isolation of the worker camps (quite far away from local communities) will help to minimize an overloading of worker-local community interactions, which should help reduce social and cultural conflicts, as well as the risk of spread of communicable diseases.

For specific siting and layout of the worker camps (temporary and permanent), a detailed topographical survey is required, to support maintenance of large trees, terracing of land, proper site drainage, location of septic tanks and soak-aways (as far away from watercourses as possible), a solid waste storage area (for onward transfer to the local landfill), and appropriate safe fuel storage. Good planning, before development of the worker camps, will address almost all potential negative impacts associated with a worker influx. The area near the National Park will be fenced (a high galvanized steel chain link fence) to prevent easy access to the park. Luckily, this area of the park has a very steep slope, and it is actually almost impossible to enter the park here and climb to higher ground. The Nikachhu itself will provide a barrier until work on the cofferdam starts.

Dissemination sessions and signage in the worker camps will clarify the rights and responsibilities of the workers regarding interactions with local people (including communicable disease risks, such as HIV/AIDS), work site health and safety, waste management (waste separation, recycling, and composting), and the illegality of poaching. Their individual contracts could emphasize these points, with appropriate conditions of employment. Chapter IX of the Labor and Employment Act of Bhutan (2007) clarifies details on the occupational health and safety of workers, which are mandatory in the construction industry. In particular, any casualty or injury resulting from occupational activities should be compensated. The law also addresses the need for safety equipment (helmets and boots, for example), as well as evacuation of injured workers to a health care center and communication arrangements (all work sites will have radios and mobile communication for this and other purposes, and a vehicle on stand-by). The Nikachhu project will also support a health clinic for workers.

6.3.1.4 Construction Equipment Mobilized

There are at least six potential impacts that are associated with the mobilization of construction equipment, especially the trucks (up to 150): increasing the risk of accidents on the roads (a risk to the local community, and road travelers); potential “wear-and-tear” (damage) due to heavy equipment and truck traffic; safety risks for workers; noise and localized reductions in air quality (from emissions and dust); loss of visual aesthetics; and, potential disturbance of wildlife, especially in the biological corridor. For the most part, these are unavoidable risks, but they can certainly be

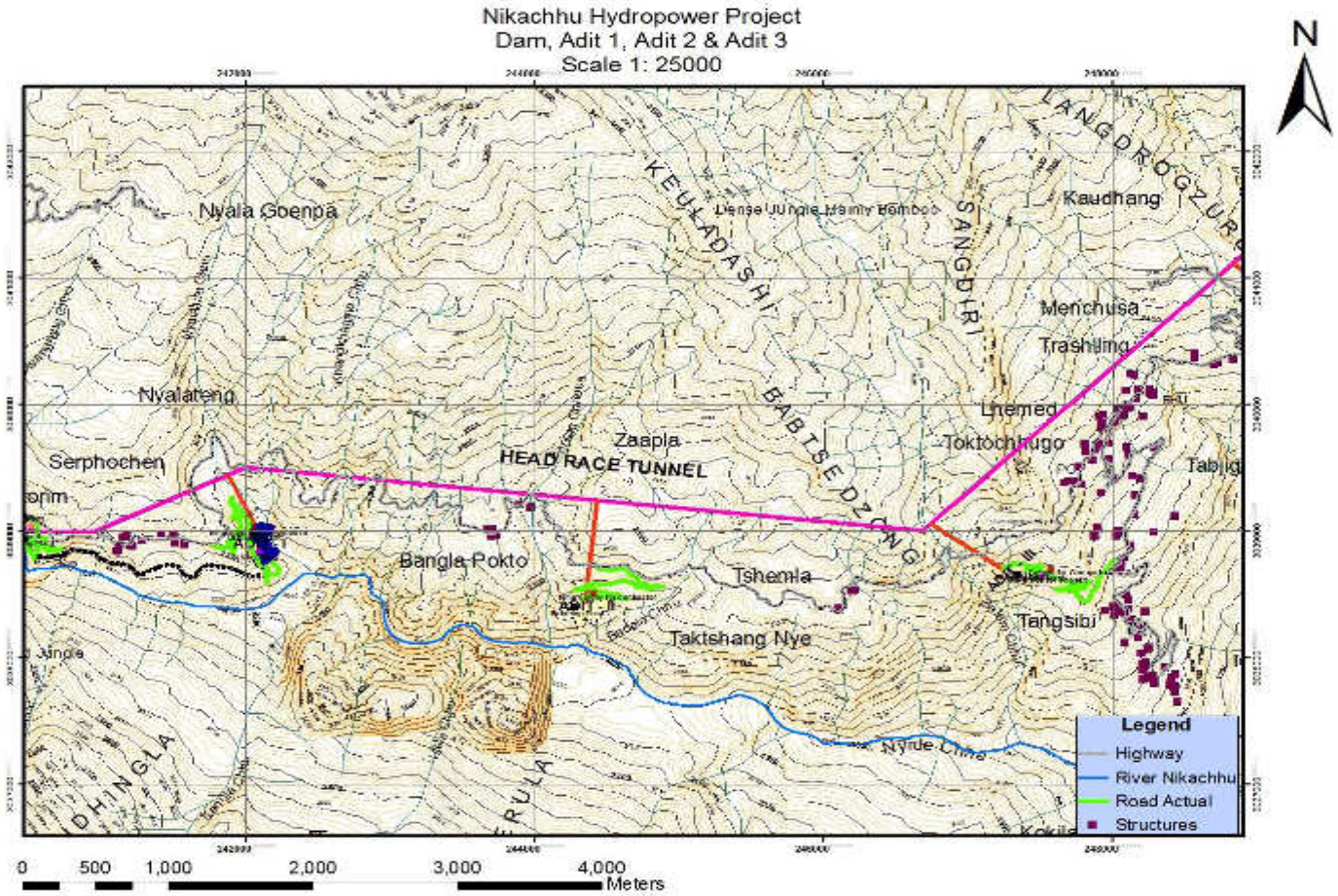
minimized, and in the end, they will be transient, associated with the pre-construction and construction phases.

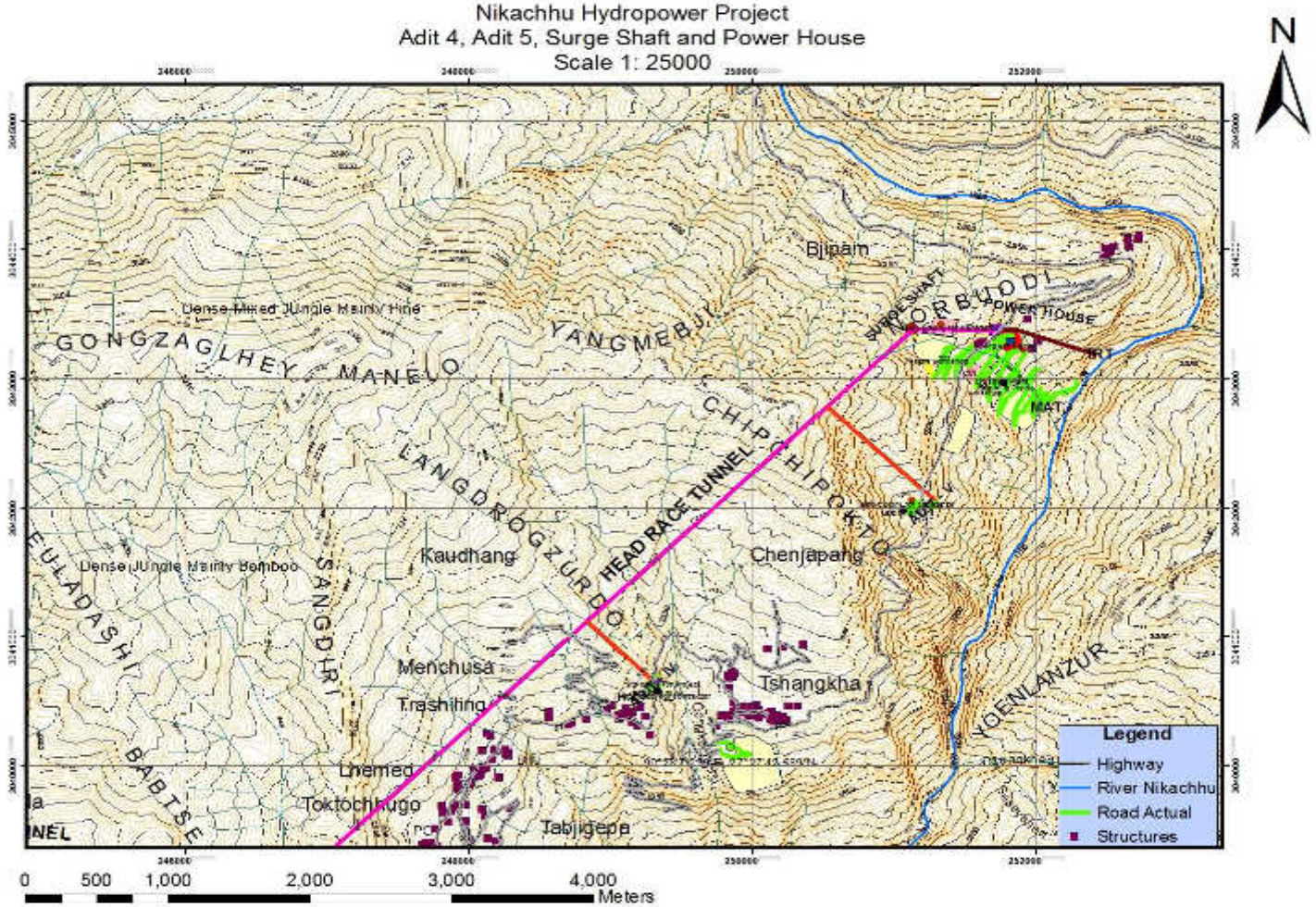
Surveys in July 2012 indicated that the Thimphu-Trashigang National Highway in the project area averages about 100 vehicles/day. The Nikachhu Project will add about 150 vehicles to this traffic load (more than doubling it during peak construction), although much of the truck and other equipment traffic will be off the highway. This means traffic density may go from the current 8 vehicles per hour to about 20/hour (at times), or one vehicle every 3 minutes, in the worst scenario. This may lead to some confusion about rights of way, and will certainly increase the risk of accidents and will delay the traffic flow, making local journeys longer. The heavy equipment may also stress the load factor of the current highway (some equipment may be 16 tonnes). Where sections of the highway are not paved, there will be an issue with generation of dust, although luckily there are few communities located along the highway in the project area. Dust will mainly be an issue for project workers, who will be required to wear masks.

Mitigation: As noted above, most construction equipment and trucks will be located on the access roads and at the work sites (and most of these will be mobilized in the construction phase). The actual location of construction equipment, most of the time "off road", is an important mitigating factor, in terms of reducing risk of accidents, limiting the exposure of local communities to noise and dust, and reducing the negative visual impact of construction equipment in such a pristine environment. To help reduce traffic snarls and risk of accidents, signs will posted at frequent intervals along the National Highway, and flag persons can be used for areas that may be congested with project construction equipment. There will also be a concerted effort at the beginning of the project to upgrade parts of the National Highway that will be used by project vehicles, so that narrow sections and blind curves (so-called "chokepoints") do not create a high accident risk. All of this can be well-planned, with suitable analysis of the existing highway and proper sequencing of tasks. There will also be provision for making repairs to the National Highway (at the end of the construction phase) that may be required as a result of damage caused by project vehicles and equipment.

With regard to mitigation of dust, vehicle emissions, and noise, standard procedures are already in place in Bhutan, including the topical water spraying by trucks every two hours (without over-watering and creating muddy areas). Workers will be required to wear face masks in particularly dusty areas, where construction equipment is working (and will wear ear plugs at noisy locations). Vehicle emissions and noise from equipment can be mitigated to some extent by the use of mufflers and emission control devices, which would be required to meet vehicle standards in Bhutan, in any case. Luckily, as noted before, most construction equipment will be working well away from local communities, which will therefore not be frequently exposed to these nuisances. In fact, there are only three houses which are 90-100 meters away from construction works areas (see graphic

below); the rest are much further removed from project work areas. Noise levels at the nearest sensitive receptors (the three houses noted above) will be routinely monitored. If there are complaints, or noise levels exceed Bhutan standards, noise barriers will be installed.


Nikachhu Hydropower Project
Dam, Adit 1, Adit 2 & Adit 3
Scale 1: 25000
N
Nyala Goenpa
Kaudhang
Menchusa
Trashiling
Nyalateng
Lnemed
Toktochhugo
Tabjig
Serphochen
Zaapla
HEAD RACE TUNNEL
Bangle Pokto
Tshemla
Taktshang Nye
Tangsibi
Jingle
Nyile Chhu
KEULADASHI
SANGDIRI
BABTSEDZONG
LANGDROGZUR
Legend
Highway
River Nikachhu
Road Actual
Structures
0 500 1,000 2,000 3,000 4,000
Meters


Nikachhu Hydropower Project
Adit 4, Adit 5, Surge Shaft and Power House
Scale 1: 25000
N
Bjipam
Dense Mixed Jungle Mainly Pine
GONGZAGLHEY MANELO
YANGMEBJI
SURGE SHAFT
ORBJIODI
POWER HOUSE
MAT
CHIPCHIPOKTO
LANGDROGZURDO
HEAD RACE TUNNEL
Dense Jungle Mainly Bamboo
Kaudhang
Chenjapang
Menchusa
Trashiling
Tshangkha
Lnemed
Toktochhugo
Tabjigepa
KEULADASHI
SANGDIRI
BABTSE
YOENLANZUR
Legend
Highway
River Nikachhu
Road Actual
Structures
0 500 1,000 2,000 3,000 4,000
Meters

Construction equipment will be required to make the access road and prepare the muck disposal area in the biological corridor. These activities cannot be prevented. However, as noted before, only 12-15% of the width of the corridor will be tied up in construction activities, temporarily (about 2 years), so wildlife will have natural options to skirt around noisy construction areas, and also move at night, which would reduce concern for interactions between construction equipment nd wildlife within the corridor.

6.3.1.5 Fuel Storage

Proper fuel storage will preclude any risk of negative environmental impacts and risk of accidents (concern for human safety). Standard practice requires storage of fuel at a flat, properly drained, isolated, fenced, and bunded area, where any slow or fast leaks of fuel will be contained, so that an explosion risk is minimized, and fuel cannot enter any adjacent watercourses. The exact location for project fuel storage will be determined later, but will meet the requirements noted above and will be in an optimal location to reduce travel time between the fuel depot and work areas.

6.3.2 Construction Phase

6.3.2.1 Influx of Workers (Worker Camps)

Many of the activities and possible impacts described above (pre-construction phase) will continue at an expanded scale in the construction phase. This means more workers, increased number of work locations, more frequent movement of construction equipment, and higher volumes and more locations for fuel storage. The impacts and required mitigation measures are exactly the same in many cases, in terms of activities, locations, and degrees of concern. It is expected that the planning and experience in the pre-construction phase will set the stage for effective planning and mitigation measures in the construction phase.

With a full workforce during the construction phase, more waste will be generated at the worker camps, and a strict regimen of sorting, re-use, recycling, and composting (mostly for kitchen wastes) will be required (as per the Waste Prevention and Management Aact 2009), with at least weekly collection of the various collected waste materials (waste collection bins for various materials will be placed at all work locations). While some materials might be handled on site (for example, composting of organic materials, which might then go to a District facility), recycled materials will have to be trucked to Trongsa for onward sorting and disposal, and residual solid waste will have to go to a designated landfill site, away from settlements and water sources. This site will have to be selected in consultation with the Dzongkhag Environment Officer and Geog Gup. Regular collection of wastes would then be established. Oil and grease will receive special attention, and will be collected, stored, and sent to recycling plants where these materials can be

properly handled. All the required waste handling procedures will be disseminated and monitored, so that all workers will know the routine, and all waste management arrangements will become conditions of contract with the various selected contractors.

Coordination with the local landfill operations will require special attention, as the current landfill for Trongsa area is filling up, and there are demands from the Mangdechhu Hydropower Project as well. Discussions are underway regarding creation of a new landfill in either Langthel or Drakten; as these develop, the possible waste volumes from both the Mangdechhu (winding down) and Nikachhu projects will obviously have to be considered. Some further mitigation can be achieved by separating waste at source, by trucking plastic to Thimphu (for the company "Greener Way"), and by using a waste compactor at the new landfill site. Detailed landfill site location investigations should include the following criteria: avoiding dense forests, environmentally sensitive areas, and geologically sensitive areas near faults, landslides, or wetland areas. The chosen area must be acceptable to the nearby community and also accessible enough to keep transportation costs to a minimum. Generally, the following distances will need to be maintained:

- between 15 m and 50 m from any property boundary, of which the 15 m closest to the boundary must be reserved for natural screening;

- minimum of 300 m from residences, water supply sources, water intakes, hotels, restaurants, food processing facilities, schools, monasteries, or public parks;

- minimum 100 m from the nearest surface water; and,

- minimum 100 m away from an unstable area.

The design of the new Trongsa landfill must ensure minimal environmental impacts and risks in itself, and ensure compliance with any criteria issued by NEC. This design must also be approved by the Dzongkhag Environmental Committee/NEC and must be located at least 1.2 m above the seasonal high water table, must include details of intermediary cover, final cover, leachate management, gas venting or recovery requirement, access road, fencing, signboard, waste compaction and covering, operation and maintenance plan, and a final closure plan. The Nikachhu project will assist this process by accurately estimating its solid waste volumes for different categories of waste over the project period. Worker and public awareness raising with regard to waste reduction and management, and use of any new facilities, will be accommodated in District and project capacity-building programs (for example, the Druk Green "Being Green, Race Against Waste" program).

All temporary worker camps will be dismantled and rehabilitated at the end of the construction phase. This will include dismantling and covering the septic tanks and soak-away pits with an adequate amount of soil, cleaning up all debris, and ensuring that the sites are fully replanted with appropriate species.

6.3.2.2 Construction Equipment Mobilized

All issues with construction equipment used in the construction phase are the same as those described in Section 6.3.1.4 above (pre-construction), and also these will be occurring in the same locations (therefore, see Section 6.3.1.4).

6.3.2.3 Fuel Storage

Fuel storage requirements will increase during the construction phase, but the issues and proposed mitigation measures are the same as those described for pre-construction (see Section 6.3.1.5).

6.3.2.4 Blasting

Blasting is a necessary part of making road cuts in some areas where bedrock occurs right at or near the surface, and may be required in some other locations as well (starting the adits, for example). As noted previously, blasting will be undertaken in a manner that avoids wide dispersal of flying rocks and the creation of landslide risk. Apart from this blasting method, there is little else that can be done to mitigate the noise and vibration associated with blasting, the possible disturbance of wildlife (except to avoid blasting at night, when most wildlife would be moving around), and the risk of localized fractures in geology that might change the aquifer dynamics in a given area. These effects, however, can be monitored to determine if any problems are developing. Blasting protocol will be managed to minimize any safety concerns (this involves posting the blasting schedule and locations, clearing the area and checking, and using a warning signal), and all explosives will be stored in a secure, locked location.

DGPC now has considerable experience in controlled blasting techniques, which have been used effectively to avoid associated impacts at the Dagachhu and Mangdechhu hydropower project sites. In any case, because the main concern is damage to adjacent structures, a data collection and mapping program for structures and buildings near the prospective blast zones will be undertaken, including photographs of structures and buildings before and after blasting. If there are any concerns or claims, these photographs can be consulted to objectively determine any possible effects from project blasting.

6.3.2.5 Quarry Operation

The final selection for a quarry site for the Nikachhu project is still underway; current studies indicate that the most feasible site may be "Longtoe", which is on the National Highway, in a degraded forest area (there is also an option to explore the outsourcing of quarry operations which might serve other needs within the district). As such, the assessment of impacts associated with a specific site cannot be completed (although the Bhucore tree survey included the current proposed quarry site); however, an assessment of generic impacts and a mitigation plan that is pertinent to any quarry operation can be undertaken here, such that quarry operations at the location that is ultimately selected can be done without creation of unacceptable environmental and social impacts.

The quarry operation will involve almost exactly the same activities and operations that will characterize the other project component sites: for example, mostly blasting, generation of noise and dust, and truck traffic. Quarries can also significantly modify landscape and topography, and usually result in a negative visual aesthetic, unless hidden from the road and local communities. This latter point is perhaps the most important, and whichever quarry site is chosen eventually, all efforts should be made to route the access road to the "back" of the quarry, and work the selected mountain or hill from a location that cannot be seen from the road. This will also eliminate noise and dust problems along the public road or highway that will connect the quarry to the project sites. This would leave truck traffic on public roads as the main issue. This can be addressed by having quarry trucks moving along public roads during low traffic hours (this would be early morning, and at night). The quarry will need to be fenced off, to avoid public safety issues, and also to keep larger wildlife from entering this work zone (most wildlife would give the quarry a wide berth, in any case, due to the noise, loss of habitat, and human activity). The quarry site will also need to be carefully designed and managed to ensure proper site drainage and keeping mobilized sediments on site with checkdams and sedimentation ponds. These are all standard quarry operating procedures, and would need to be documented as such. Presumably, the selected quarry would have an economic life beyond just the Nikachhu project; however, when it is depleted, it would need to be rehabilitated as much as possible, so that it can assume a natural state.

For the quarry workers themselves, airborne particulates pose a potential health risk; these can lead to respiratory, dermal, and ocular irritation or damage. The particular concern in some stone quarries is inhalation of dust containing silica, which can lead to silicosis (a serious lung disease). Therefore, the quarry staff will have to follow best occupational health and safety guidelines including: ensuring that all saws and drilling machines have adequate dust catchment or air filtration systems, particularly when the machines are situated in a confined or enclosed area where air flow is limited; using water misting to remove airborne particulates; cover rock and gravel stock piles and carrier trucks with tarpaulins; lay gravel on the quarry access roads; and, avoiding drilling and

sawing when the cloud ceiling is low or the wind is high so that dust plumes are not created in the vicinity.

6.3.2.6 Crusher Plant Operation

Activities associated with the crusher plant are very similar to the quarry operation and construction activity at the various project component sites. Therefore, the issues and possible mitigation measures are the same, and focus on management of dust and noise, as well as regulating truck traffic to minimize disturbance to local traffic flow (see details in Section 6.3.1.4 and 6.3.2.5).

6.3.2.7 Muck Generation and Disposal

Given the extent of tunneling proposed for the Nikachhu project, quite a bit of muck (a mixture of rock and clay) will be generated and will either be recycled (perhaps 10-20%, for use as material in the project), or disposed and eventually covered with vegetation at muck disposal sites. The total expected volume, to be disposed at ten disposal sites on the north side of the Nikachhu, is 1.5 million m^3,. This is equivalent to a pile of sediments 100 m wide x 20 m high x 900 m long, or roughly equivalent to a small hill, if all the muck were disposed in one location .The total area of muck disposal will be slightly less than one square kilometer; the muck disposal areas will be first cleared, then muck dumped and terraced. By the time tunneling operations are over, all muck disposal sites will be re-vegetated (groundcover and trees, most likely). They will not, however, revert to a full primary or secondary forest. Figure 6-8 shows the ratio of muck disposal area to total map area (that is considered the project area for the purpose of analysis); 0.5% of this area (at 10 sites) will be taken up by muck disposal, which is an area loss that is acceptable, especially as it will be revegetated within several years. Only the muck disposal area in the biological corridor (for Adit #2) will present a potential disturbance to wildlife, but there will be adequate undisturbed habitat on either side of this muck disposal area (at least 2 km on either side) that should provide an option for safe refuge for wildlife that need to move or stay hidden.

Figure 6-8: Ratio of muck disposal area (accumulated; 10 sites) to the map area.

The muck disposal process will generate dust, like most other project construction activities, and routine dust management (water sprinkling) will be required. The main challenge will be to manage the muck disposal so that terraced sites can develop and slope stability can be assured, and to ensure that sediments do not enter any watercourses, which will require careful study of site drainage.

Mitigation: Designated muck disposal sites will be scraped of topsoil, which will be stored close to the site for later use. Dumping of muck will be undertaken in contours (following the local topography), with each layer arranged in benches and compacted using an excavator (see Figure 6-9). When specific parts of the selected disposal site are filled to capacity, the surface will be dressed to even out the surface, then topsoil will be added and appropriate vegetation planted to consolidate the surface and reduce erosion of soil (bioengineering). It will be critically important to develop retaining walls (gabion masonry) before there is significant disposal of muck, so that it does not enter adjacent watercourses, or cause compounding slope failures. Muck will be dumped at least 30 m above the highest flood levels of streams and the river. This sequence of steps is shown in Figure 6-10.

Figure 6-9: Example of muck benching and re-vegetation.

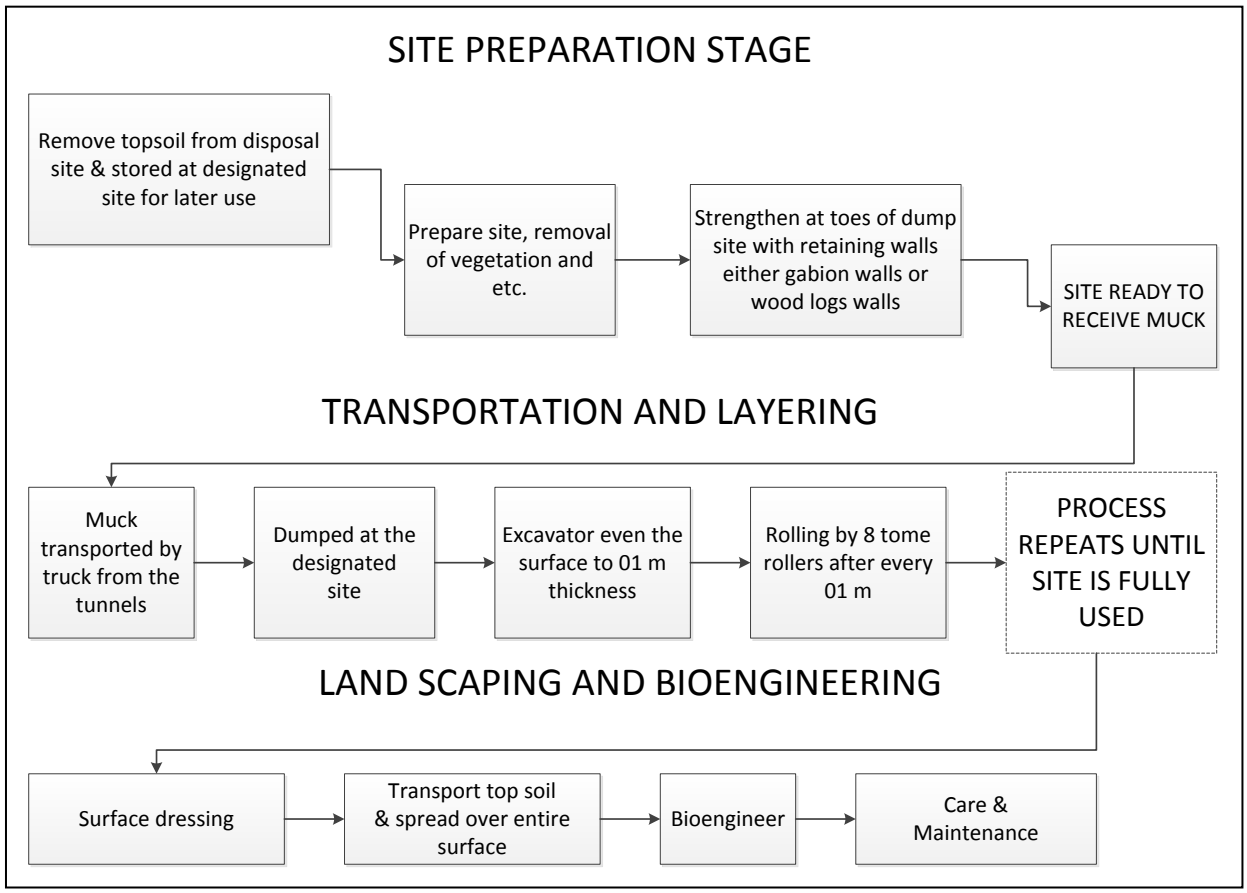


Figure 6-10: Muck disposal sequence.

6.3.2.8 River Diversion (Cofferdam)

A cofferdam will be required to create a dry work area for construction of the final diversion dam (this is standard practice in dam construction). This will create a very temporary disturbance of the Nikachhu as the cofferdam is completed (after a diversion tunnel is drilled through the right bank of the Nikachhu). There will therefore likely be some turbidity pulses in the river during cofferdam construction (which will be flushed quickly). This will in turn create transient impacts on aquatic habitat quality and possibly some disturbance of fish (short-lived).

During the period of dam construction, the river will be channeled to the diversion tunnel. This will maintain downstream discharge and accommodate regular seasonal variations, so that the river does not breach the work area. The diversion tunnel will fully accommodate movements of fish, as it is known from observations of the Dagachhu diversion tunnel that fish of various species could move above and below, and through the diversion tunnel.

The cofferdam work will be adjacent to the National Park (not in it, *per se*), on a very steep slope that does not support wildlife access to the river, so cofferdam work at the site (and other required activities at the site – the construction of the main diversion dam, for example) is not expected to significantly affect the adjacent habitat and any wildlife that it may support. It has also been observed at the Dagachhu dam site that wildlife (for example, langurs) will stay in the trees as close at 20 meters to active construction work; they do not seem to be disturbed particularly by human activity and noise, as long as they stay in their habitat, and can retreat up-slope when necessary.

6.3.2.9 Transmission Line Tower Installation (Land Clearing)

There is ample experience in Bhutan with clearing the right-of-way for transmission line alignments. For the Nikachhu project, the line will go from the powerhouse to Yurmo, where it will join the Mangdechhu HEP switch yard (a distance of about 18.6 km). The corridor or right-of-way is typically 27 m wide. For areas where the tower footings occur in agricultural land, cultivation will still be allowed, so clearing may only be required in 123.55 (49.99 ha) of forested and scrub land. Furthermore, clearing for the alignment usually only requires cutting tall trees (not the whole width and length of the right-of-way); this is especially the case where the transmission lines will span gullies and valleys and will be high above the forest cover. Sections 6.3.1.1 and 6.3.1.2 included assessment of the total area to be cleared for tower footings and forested areas under the lines (with numbers recently adjusted to reflect the alignment survey), and the risks associated with sediment mobilization (these have been assessed as acceptable, since they comprise a small percentage of the project area and do not include unique or vulnerable habitats, and trees will be replaced, in any case). In all cases, as with the dam and powerhouse components, compensation

will be paid, where needed, for temporary and permanent loss of access to land (about 4.2 (3.6 temporary (mostly SRF), 0.6 permanent by tower footing). Regarding the risk of disturbance of local communities and wildlife, the work crews for each foundation area will be small and not on-site for long, so any disturbance will be transient.

Mitigation: As with the other project component sites, land clearing, cutting of trees, and site preparation for the tower footings can be managed to minimize negative environmental impacts. All efforts will be made to fell trees so that they do not slide downhill and knock out other vegetation (Forestry staff should be involved in the selection and marking of trees in the right-of-way, as well as monitoring tree cuts during the alignment work). Previous practice suggests that this can be undertaken in a herring bone pattern (see Figure 6-11). These trees will be categorized and pulled from the site at access points that will not damage the forest or watercourses (these trees will most likely be used for fuelwood). As much as possible, large trees on the edge of the right-of-way should not be disturbed or damaged, as these are favoured habitat of the rufous-necked hornbill (which is protected). As with other project areas where trees will be cut, the potential loss of bird and wildlife habitats can be countered by planting suitable trees at other locatios which are currently degraded (habitat enhancement in those areas). Tower footings will be located at stable locations, and site preparation will ensure that sediments are not mobilized unnecessarily (however, each tower might require excavation of up to 400 m^3 of sediments for the concrete foundation). Once the tower footing foundations are poured, sediments will be placed back against the footing, and the site re-vegetated (low elevation species), along with site drainage channels, to reduce the erosion risk.

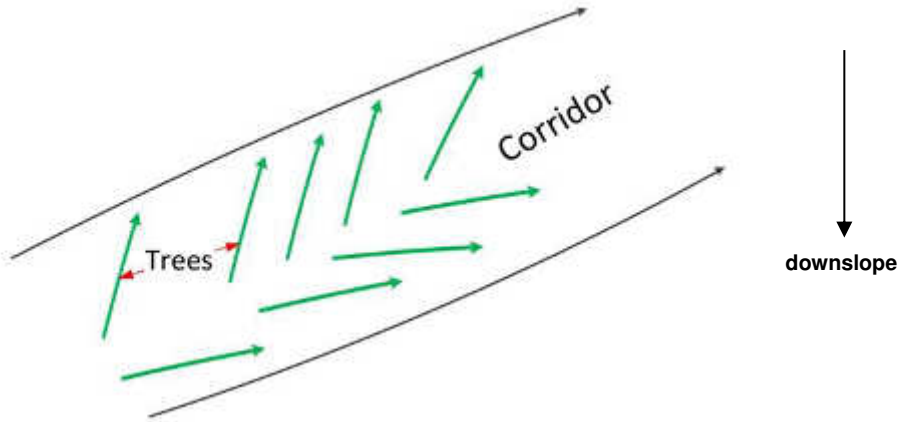


Figure 6-11: Proposed felling method for trees along the transmission line corridor.

6.3.3 Operation Phase

6.3.3.1 Reduced Worker Numbers

With the completion of project construction work, the area will see an exit of most of the workers, and any associated negative impacts will fade (just permanent project staff will remain). At the same time, the business opportunities (including local employment) that will have been associated with the pre-construction and construction phases will come to an end. This may be experienced as a negative economic shock, since there are not any obvious plans for other large infrastructure development projects in the Trongsa area to maintain a high level of economic activity in the immediate area. This negative "turn" needs to be broadly disseminated from the beginning of the project, since local people are already experiencing the positives of the Mangdechhu project and will feel secure in the future, as the Nikachhu comes along to replace the economic activity.

The Nikachhu project proposes to create a buffer against the possible negative economic shock, by implementing a Community Development Program, which will involve setting aside a fund to provide grants for such activities as the following:

- mitigating wildlife-human conflicts, by providing electric fencing to protect crops;
- supporting roadside produce vending (stalls and shades near the roads); and,
- training communities in vocational skills.

The implementation of the fund will require setting clear criteria and an objective selection process, so that all local communities have fair access. The expenditures and results from community investments will then be monitored and reported publicly.

6.3.3.2 Diversion Dam and Reservoir Operation (Flooded Area)

Once the project construction is completed and the project is operational, with work sites rehabilitated, the main change produced by the project will be the altered hydrology of the Nikachhu, which will be directly associated with the reservoir (created by the dam operation), diversion of most discharge to the headrace, and the maintenance of minimum environmental flow below the dam. Each of these has specific environmental implications, so they are discussed separately.

The submergence of forest area due to reservoir development behind the diversion dam will be a total of about 12.28 acres (4.9 ha; see Figure 6-12), a waterbody about 810 meters long (about 60 m wide near the dam, then tapering to the west). Given the cross-section of the gorge at the dam site, most of the flooded area (about 70%) will be on the left bank of the river in degraded forest (between the Nikachhu and the national highway), rather than on the National Park side of the river

(the right bank). Only 6 acres (2.4 ha) of the park area (within the buffer zone) will be permanently flooded. This is 0.0014% of the whole Park, in an area that, because of the very steep slopes, is not used by wildlife for access to the river, and cannot be used by people to enter the park. As such, the reservoir impingement on the edge of the park will likely have a negligible (unmeasureable) effect on the park operations (there are no park activities or facilities there, and no specific restrictions noted in any Park documents; also note that there is no specific National Park Management Plan for JSWNP), the broadleaf habitat in this area (of which there is much in adjacent areas), and wildlife, which will continue to have extensive scope for refuge and movement in all other areas within the park on the south side of the Nikachhu.

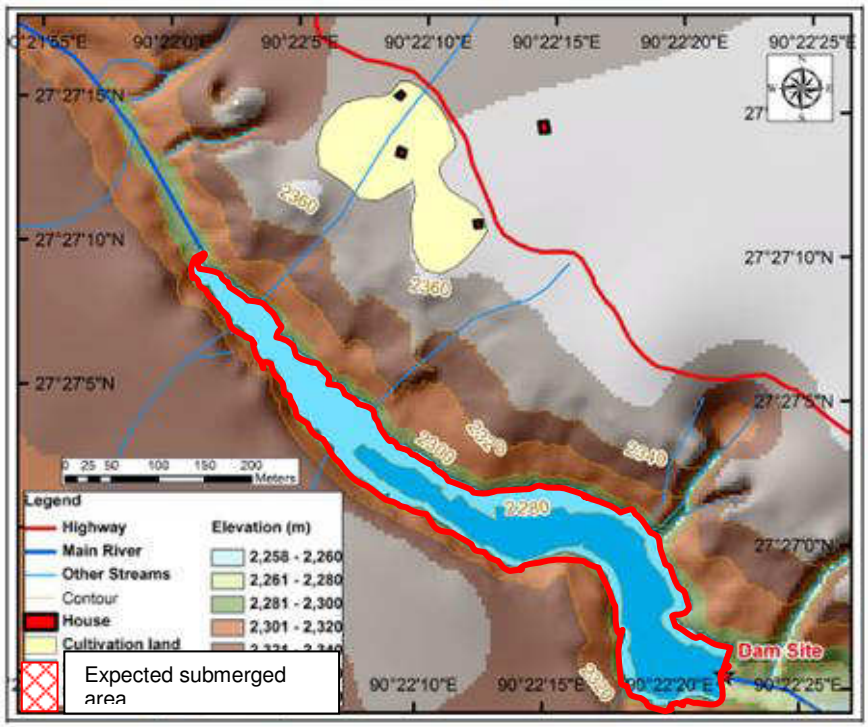


Figure 6-12: Expected submergence area above the diversion dam.

The vegetation in the area to be flooded will be thoroughly cleared (all trees and groundcover), so that there is less risk of organic breakdown of vegetative matter in the flooded area and subsequent water quality issues. The reservoir then has some potential as a more quiescent aquatic habitat, in which other fish (other than brown trout) could be stocked (Bhutan guidance requires some consideration of a fisheries development plan, which might include stocking with native species, such as snow trout, subject to proper scientific assessment of its feasibility), and which waterfowl might be able to use as a roosting and feeding area. There is also potential to open the left bank side to public access and interpretation for National Park features, since the access road will be in place and the reservoir will be a significant visual enhancement in this area (this needs more discussion and study, especially to address potential safety issues if there is public access to the left bank). The National Park side of the reservoir would be completely fenced, to prevent any public access in that area. Fencing might be required on the left bank as well, to keep cattle and

people out of the reservoir (but not necessarily away from the banks of the reservoir). In general, most of the Nikachhu itself, and the steep right bank border of the Park, are quite inaccessible to people, from the dam site down to the confluence with the Mangdechhu. Nobody can climb up the rock face on the Park side of the Nikachhu at the dam site, and most people would not want to as they could not take in equipment and cut trees or hunt; there are many locations along the highway for this kind of activity, and there are community forests anyhow. In any case, JSWNP staff will be available for vigilance and monitoring, and this is budgeted in the EMP.

Apart from logs which might enter the reservoir, and which will need to be regularly extracted by a patrol boat, the reservoir should maintain good water quality, as almost all the watershed above the dam site is thickly forested, has no paddy cultivation, and has very few exposed slopes that could be subject to landsides. There is little sedimentation of the Nikachhu as a result (apart from occasional high turbidity events in the monsoon, which affect all rivers in Bhutan). In any case, the water flow through the reservoir will be constant (as this is a run-of-river scheme), so there will be a very high flushing rate. A specific watershed management plan is therefore not expected to be required, as the current forest management rules provide the required protections against undue sedimentation.

As most of the water entering the reservoir area will be channeled to the intake for the headrace (for power generation), fish in this part of the reservoir may be entrained in the higher velocity currents near the intake (the main concern is for brown trout, the only fish species which have been recorded in the Nikachhu). Therefore, a series of screens will be required to keep fish from the immediate intake area, and will be designed to allow fish to approach the screens but not be impinged on them, so that fish can move to the spillway and continue downstream. Screens can be made of various materials, such as perforated plates, metal bars, wedgewire, plastic, or metal mesh. The objective is to create uniform velocities and eddy-free currents upstream of the screens to effectively guide fish towards the bypass or spillway (see Figure 6-13 for examples).

Figure 6-13: Example of fish screens at hydropower intakes.

While brown trout will be able to go downstream, they will not be able to get past the diversion dam to go upstream (the field survey data indicate that trout may be confined to the area at and above the dam site, in any case). Brown trout do not undergo extensive river migrations; in this area, they cannot get past the waterfalls and cascades on the Nikachhu. As introduced fish, they do not have a specific ecological niche value; in fact, they seem to have outcompeted snow trout in some parts of Bhutan, and can be considered a nuisance species, as a result. Therefore, no particular provision is required to allow fish to get upstream past the diversion dam. Brown trout will continue to breed above the dam, and below as well (if in fact they occur in the Mangdechhu; but they have not been observed there). Any other fish that occur in the Mangdechhu and at the confluence of the Nikachhu and the Mangdechhu have never been able to get past the cascades and waterfalls on the Nikachhu in any case, so their possible presence in the downstream of the Nikachhu and the Mangdechhu is not an issue for the project. They will continue to have at least minimum environmental flow in the Nikachhu, and increasing accumulated tributary flow between the dam and the confluence of the Nikachhu and Mangdechhu, especially in the section below the waterfalls, where most fish are likely to occur (not being able to get past the falls; see Section 5.2.6 for the locations of these waterfalls).

Finally, the downstream side of the diversion dam will present a negative visual aesthetic, but this side of the dam will not be visible from the highway, as there will be a significant strip of forest retained between the highway and the dam site. The upstream side of the dam will present a positive visual aesthetic, as noted above, due to the creation of the reservoir.

6.3.3.3 Maintenance of Minimum Environmental Flow

The Nikachhu is a tributary of the Mangdechhu, with its catchment area of 373 km^2 at the dam site and 453 km^2 at the confluence with the Mangdechhu. There are no glacial lakes in the catchment and therefore the project area is free from the risk of Glacial Lake Outburst Flood (GLOF). The catchment is supplied with snow-melt water and rainfall, most of which is channeled through many smaller tributaries that join the Nikachhu. The main feature of the physical environment that the project is dependent on and which the project is likely to impact especially during operation is the hydrology of the Nikachhu downstream of the dam which in turn may impact the aquatic ecosystem (see the Hydrology Annex, which includes primary hydrological data, and analysis based on those data).

As per the Guidelines for Hydropower Projects (May 2012), the following four methods of determining e-flow have been provided:

a) **Hydrology based:** Sets flow on assumption that maintaining some percentage of the natural flow will keep the river wet and fulfill all requirements.

b) **Hydraulic rating:** Measures changes in the river flow, based on a single cross-section, (perimeter, depth, velocity) to assess changes in the habitat affected by it.

c) **Habitat simulation:** Employs multiple cross-sections to the hydraulic model rating to simulate the conditions in a given stretch of the river.

d) **Holistic methodologies:** Employs a multi-disciplinary approach to provide a consensus view. The team could include hydrologists, biologists, geo-morphologists, water quality specialists and socio-economists.

In the case of the Nikachhu Project, the Hydrology based method has been adopted in view of the following:

i. Steep nature of the river downstream of the dam

The Nikachhu is a very steep river with numerous major falls along its course from the dam site until its confluence with the Mangdechhu. Within a stretch of about 6 km from Chendebji Chorten at elevation of about 2,400 masl, the river drops by about 138 meters to the dam site at elevation of 2,262 masl. The average river gradient in this reach is about 2.3%. From the dam site to the confluence, the riverbed drops from 2,262 masl to 1,400 masl, dropping 860 m over a reach of about 10 km giving the slope of 8.62%. The waterfalls are clearly associated with the northwest-southeast traverses that the Nikachhu makes across the prevailing northeast-southwest ridges that connect the mountain systems on either side of the Nikachhu. Figure 6-14 shows the river profile of Nikachhu from Chendebji Chorten until its confluence with theMangdechhu.

Figure 6-14: River profile of the Nikachhu.

From the above figure, it is seen that there are numerous major waterfalls particularly in the stretch between the dam site and the confluence with the Mangdechhu. Most of the major waterfalls located downstream of the dam could not be accessed due to steep and densely vegetated terrain. However, some of the waterfalls which were accessible were documented and provided in the Figure 6.5 below.

Figure 6-15: Waterfalls and rapids in the Nikachhu.

In view of the steep river profile with numerous major waterfalls, dense vegetation, rugged topography and inaccessibility, a river survey along most stretches downstream of the dam could not be carried out.

ii. Contribution from perennial downstream tributaries

There are numerous tributaries contributing to the Nikachhu (6 major and 23 minor tributaries). The first stream joins the Nikachhu at a distance of about 800 m downstream of the dam. Of the numerous streams, there are six major streams between the dam site and the confluence of the Nikachhu and Mangdechhu as shown in Figure 6-16 below.

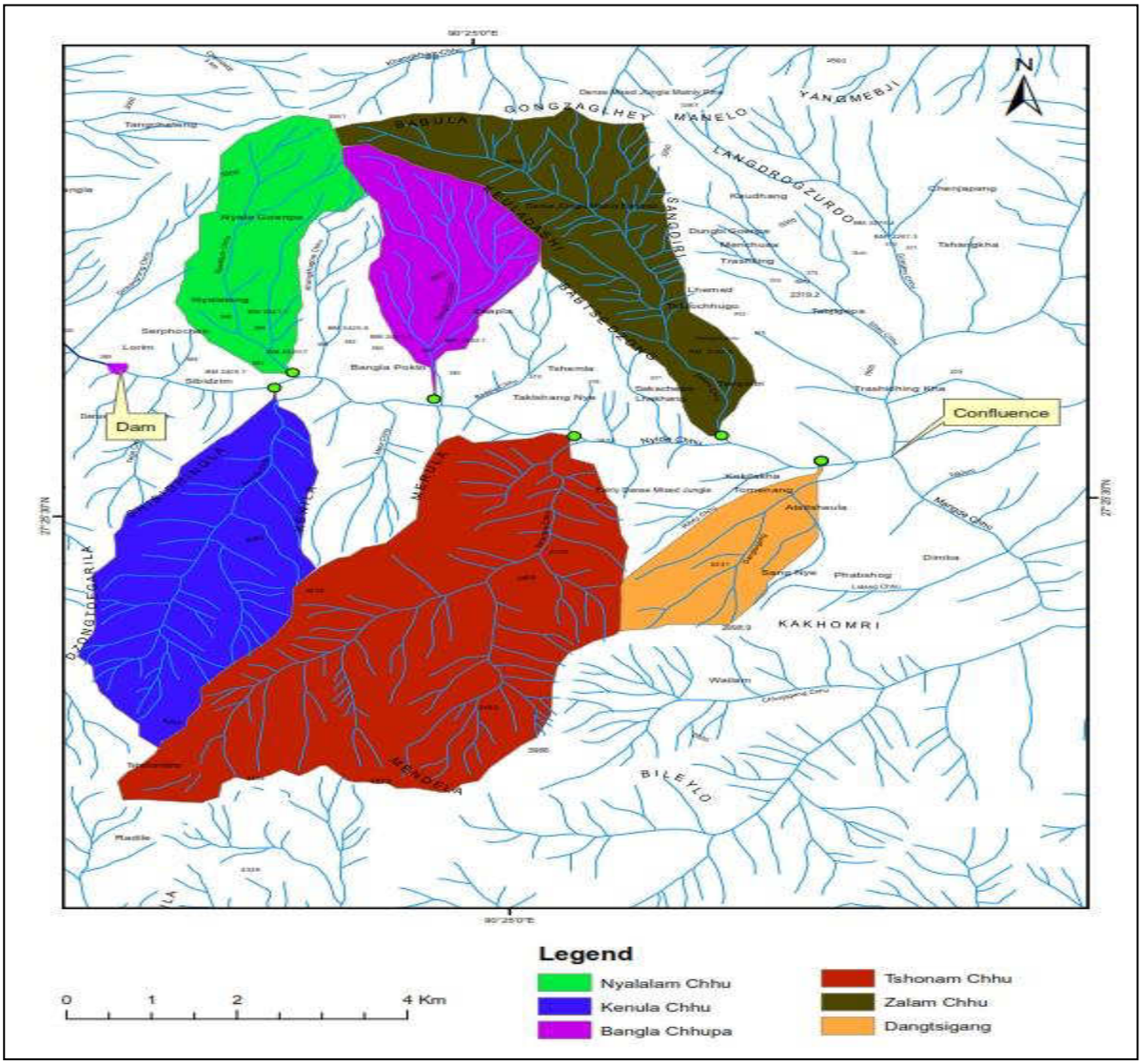


Figure 6-16: Streams between dam and confluence of the Nikachhu and Mangdechhu.

The details of the six major streams are given in Table 6-4 below.

Table 6-4: Six major tributaries between the dam and confluence.

Name of tributary	Bank	Distance from Dam (km)	Catchment area (km^2)
Tshonamchhu	Right	6.33	21.09
Kenulachhu	Right	2.7	9.88
Zalamchhu	Left	8.05	9.33
Nyalalamchhu	Left	2.44	5.66
Bangla Chhupa	Left	4.36	5.12
Dangtsigang	Right	9.74	3.74
		Total catchment area (km^2)	**54.82**

The catchment area up to the dam site is 373 km^2 and up to the confluence is 453 km^2; therefore the catchment area between the dam site and the confluence of the Nikachhu and Mangdechhu is 80.5 km^2. By the method of catchment area ratio, the minimum contribution at the confluence from the tributaries is 0.86 m3/s in the month of February. The average monthly flow at the dam site and contribution from the catchment downstream of the dam is as shown in Table 6.5.

Table 6.5: Average monthly flow at dam site and contribution from downstream catchment.

Month	Pre-project flow at dam site	Contribution from downstream Catchment
	m^3/s	m^3/s
Jan	5.11	0.91
Feb	4.84	0.86
Mar	5.51	0.98
Apr	7.90	1.40
May	13.00	2.31
Jun	22.27	3.95
Jul	37.86	6.72
Aug	39.74	7.05
Sep	29.27	5.19
Oct	15.37	2.73
Nov	8.42	1.49
Dec	6.01	1.07

By the same catchment area ratio method, the contribution from each of the six major downstream tributaries is given in Table 6.6.

Table 6.6. Flow contribution from each of six major streams.

Month	Contribution from major Tributaries					
	Tshonamchhu	Kenulachhu	Zalamchhu	Nyalalamchhu	Bangla Chhupa	Dangtsigang
	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
Jan	0.29	0.14	0.13	0.08	0.07	0.05
Feb	0.27	0.13	0.12	0.07	0.07	0.05

Month	Contribution from major Tributaries					
	Tshonamchhu	Kenulachhu	Zalamchhu	Nyalalamchhu	Bangla Chhupa	Dangtsigang
	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
Mar	0.31	0.15	0.14	0.08	0.08	0.06
Apr	0.45	0.21	0.20	0.12	0.11	0.08
May	0.73	0.34	0.33	0.20	0.18	0.13
Jun	1.26	0.59	0.56	0.34	0.31	0.22
Jul	2.14	1.00	0.95	0.57	0.52	0.38
Aug	2.25	1.05	0.99	0.60	0.55	0.40
Sep	1.65	0.78	0.73	0.44	0.40	0.29
Oct	0.87	0.41	0.38	0.23	0.21	0.15
Nov	0.48	0.22	0.21	0.13	0.12	0.08
Dec	0.34	0.16	0.15	0.09	0.08	0.06

Department of Hydro-met Services (DHMS) has been collecting spot data once a year during the leanest seasons at Zalamchhu as given in Table 6.7. As seen from Table 6.7, the average leanest flow over the period of 18 years works out to be 0.12 m^3/s and from **Table 6.6** the flow from Zalamchhu during the leanest seasons is also 0.12 m3/s which validates the data calculated by the catchment area ratio method.

Table 6.7: Spot data collected by Department of Hydropower and Power System at Zalamchhu.

Date of Measurement	Year	Discharge m^3/sec
25.01.94	1994	0.149
02.01.95	1995	0.127
22.01.96	1996	0.167
21.02.97	1997	0.124
23.01.98	1998	0.123
29.01.99	1999	0.11
11.01.00	2000	0.119
06.02.01	2001	0.098

23.02.02	2002	0.102
07.02.03	2003	0.142
11.02.04	2004	0.119
19.02.05	2005	0.161
13.02.06	2006	0.113
12.03.07	2007	0.109
17.02.08	2008	0.111
19.02.09	2009	0.099
22.02.10	2010	0.082
27.03.11	2011	0.089
Average flow		***0.12***

From the above, it is seen that there are major perennial tributaries downstream of the dam which are contributing significantly to the flow in the Nikachhu. The flow data in the major tributaries have also been validated based on the observations maintained by DHMS.

iii. Migratory Fish

As noted previously, the only fish caught during the first survey (July 2012) was the brown trout (*Salmo truta*; only from a location above the proposed dam site; not at the confluence with the Mangdechhu and not in the Mangdechhu itself). This dominance by one fish species was further confirmed through different consultations and discussions with the local community and Mr. Phuntsho (from Chendebji, once in-charge of the Royal fishing spots). The brown trout was introduced to the Nikachhu in the late 1960s (it is originally a European species). Mr. Phuntso noted that while fish cannot migrate up the Nikachhu, due to the waterfalls, the brown trout may have migrated downstream as far as the confluence with the Mangdechhu (although none of the Nikachhu project surveys or the Mangdechhu project survey recorded it at the confluence or in the Mangdechhu). Furthermore, given the relatively high altitude (very few fish are expected above 2,000 m asl), cold water, and rough conditions in the Nikachhu, important fish such as the mahseer (*Tor* sp.), do not occur there. The Mangdechhu has more fish, being a bigger river at lower altitude, and asla (*Schizothorax progastus*), snow trout (*Schizothorax richardsonii*), and copper mahseer (*Acrossocheilus hexagonolepis*) are listed for that river, as well as other mahseers, catfish, carp, and some smaller resident fishes. These do not manage to get up the Nikachhu, as waterfalls start about 100 meters from the confluence. Fish sampling in December 2012 confirmed that the only fish in the Nikachhu above the confluence with the Mangdechhu is the brown trout (and it was

only found at the dam site and above, not at the confluence itself). The December 2012 survey also confirmed the common presence of snow trout (*Schizothorax richardsonii*) in the Mangdechhu.

From the finding of the EIA study and based on the site condition at Nikachhu, the habitat for fishes between the dam and confluence is not critical.

iv. Downstream users

There is no settlement downstream of the dam until the confluence with the Mangdechhu. All the settlements are located on the slopes and water usage is mainly from the tributaries of the Nikachhu and the main Nikachhu river is not used by the people. The Google image showing the dense forest along the downstream stretch of the dam until the confluence is as below.

Figure 6-17: Stretch of Nikachhu from dam to confluence.

In view of the above reasons, the hydrological basis has been considered in determining the e-flow of the Nikachhu project. The other methods were found not feasible to be considered for the Nikachhu due to inaccessibility to the site and difficulty in carrying out survey works.

6.3.3.4 Determination of E-flow

Table 6.8. The 90% dependable year flow of the Nikachhu at the dam site.

Month	Nikachhu Flow m^3/s
Jan	5.25

Feb	4.90
Mar	5.42
Apr	6.67
May	10.60
Jun	21.87
Jul	26.01
Aug	37.09
Sep	26.12
Oct	15.10
Nov	8.28
Dec	6.06
Average flow	**14.45**
Minimum flow	***4.90***
Maximum flow	***37.09***
Average lean flow (Dec-Mar)	***5.41***

The e-flow that has been selected reflects several stages of analysis and changes in design parameters. In the first instance, with the original design and a slightly lower dam height, e-flow was set at 5% of average lean season flow (working out to be 0.27 m^3/s, based on the average observed discharge during the four leanest months from December-March, which is 5.41 m^3/s). This was considered acceptable to the design team in terms of overall project viability (engineering aspects), and fell within the range of previous e-flow decisions in Bhutan (ranging from 3.5 to 9.6% of average lean season flow; for example, Mangdechhu has an e-flow of 1.5 m^3/s, which is 8% of average lean season flow in the Mangdechhu). With the detailed design that was undertaken in 2013, the dam height was raised slightly and the reservoir area was also increased. This gave more scope for increasing the e-flow without affecting the required power potential and overall viability of the project, so the proposed e-flow was increased to 0.554 m^3/s, slightly more than the 10% of the average lean flow of the 90% dependable year (this means a discharge that has been shown to occur in 90% of the observed years, giving reasonable confidence in the data used in the analysis). This is obviously more favourable for maintaining discharge in the Nikachhu during the lean season, compared to the first proposed e-flow.

Guidelines for calculating e-flow are still being developed for Bhutan. During the consultations for the Nikachhu project, the NEC mentioned (based on earlier studies) that the required e-flow for hydropower projects in Bhutan could be as high as 60% of the minimum flow (in the case of the Nikachhu, this would work out to about 3.2m^3/s). However, the NEC also noted that e-flow should be determined based on site specific circumstances and water requirements, including presence and needs of fish, and downstream water users. In the case of the Nikachhu, the presence of 6 major and 23 minor perennial tributaries between the proposed dam site and the confluence with the Mangdechhu, the presence of waterfalls between the dam site and the confluence that block fish migration, and the observation that only brown trout occur in the river (only above the dam site, where they were introduced years ago) were considered mitigating factors that support the proposed e-flow of 0.554 m^3/s.

Nevertheless, given the requirement to maintain some aquatic habitat in the downstream part of the Nikachhu (notably the point of confluence with the Mangdechhu, recognizing that the Mangdechhu has several more fish species than the Nikachhu, including snow trout and mahseers), and noting that the Mangdechhu will also have a dam above the confluence with the Nikachhu, which will reduce downstream discharge until the Mangdechhu tailrace, the cumulative discharges in each month in the downstream section of the Nikachhu (at the point of confluence with the Mangdechhu) and in the Mangdechhu just before the proposed tailrace site for the Mangdechhu project, when both projects will be operating, were determined. These include the contributing discharge from perennial tributaries on both rivers, which boost the discharge in both rivers in increments going from the dam sites downstream. For the Nikachhu, at the confluence with the Mangdechhu, the "with project" discharges will be as follows (percentages, based on data shown previously in this section):

- January: 24.3% of normal average monthly discharge;
- February: 24.7%;
- March: 23.6%;
- April: 21.1%;
- May: 18.7% of normal average monthly discharge, plus spillover from the dam;
- June: 17.2%, plus significant dam spillover;
- July: 16.3%, plus significant dam spillover;
- August: 16.2%, plus significant spillover;
- September: 16.7%, plus significant spillover;
- October: 18.1% of normal average monthly discharge;
- November: 20.7%;
- December: 22.9% of normal average monthly discharge.

Obviously, the actual discharge between the dam site and the confluence (where no fish are expected to occur, due to the waterfalls) will be less than the amounts shown above. Nevertheless, a nominal aquatic habitat will be maintained at all times in the narrow cross-section of the river, with monsoon variability in discharge still being evident (due to the spillover from the dam from May to October). In absolute terms, the discharge in the Nikachhu at the confluence with the Mangdechhu, "with project", will range from a low of 1.44 m^3/s in February (which is about 10% of the mean annual discharge) to 28.2 m^3/s in July. Note that most fish move within river systems when the monsoon discharges are evident, so the Nikachhu monsoon discharge ("with project") will still be quite high, allowing any fish that are in the Mangdechhu to at least enter the Nikachhu and proceed as far as the first set of cascades and waterfalls (which is within 100 meters of the confluence).

For the Mangdechhu, taking into account the "with project" discharges from the Nikachhu (noted above) and the "with project" discharges between the dam and the Mangdechhu tailrace (e-flow, dam spillover, and contributions of perennial tributaries), the monthly discharges, as a percentage of "without project" discharges, are as follows:

- January: 30.6% of normal average monthly discharge;
- February: 31%;
- March: 29.8%;
- April: 27.7%;
- May: 26.1%;
- June: 28.9%;
- July: 54.5%;
- August: 57.2%;
- September: 43.7%;
- October: 26.1%;
- November: 27.8%;
- December: 29.4% of normal average monthly discharge.

In absolute terms, discharge in the Mangdechhu just prior to the tailrace (where all the project water will re-enter), with both projects operating, will range from a low of 9.33 m^3/s in February to a high of 191.23 m^3/s in August. GoogleEarth images indicate that the Mangdechhu is about 30 meters wide near the tailrace location. This suggests that the Mangdechhu would still have at least 30 cm of water depth during the leanest month (February), with both projects operating. This is deep enough for fish to move. Primarily due to the contributions of tributaries to the Mangdechhu, the average annual discharge in the river just before the Mangdechhu tailrace (with both projects operating) will be about 42% of the average annual discharge in this part of the river (a globally acceptable

standard is 10% of annual river discharge). Furthermore, monsoon variability will be maintained, and water depth in each month will be adequate for fish movements (but obviously getting more challenging in the lean season closer to the Mangdechhu dam, with less contribution from tributaries).

At least 0.554 m^3/s e-flow (or 10% of the average lean flow of the 90% dependable year, whichever is higher) will be guaranteed for the whole operation of the Nikachhu project and will also be maintained during filling of the reservoir. It will provide fair-good flow for maintenance of the fish population at the confluence with the Mangdechhu, mostly due to the presence of numerous perennial tributaries that add another 0.995 m^3/s in the lean season. Since only one common introduced fish species (brown trout) is supported upstream of the Nikachu-Mangdechhu confluence (and this probably only occurs above the dam site, in any case; it was not found at the confluence), as long as good water quality to enable maintenance of the macro-invertebrate community can be maintained for the entire dewatered stretch, it is not considered necessary to impose a higher minimum flow in order to provide excellent-optimum flow conditions for fish downstream in the lower reaches of the Nikachhu.

E-flow releases, along with the fish population, macro-invertebrate community, and water quality, will be monitored at both downstream of the dam site and in the lower reaches of the Nikachhu. If subsequent monitoring of the aquatic habitat indicates that an e-flow of 0.554 m^3/s is inadequate to maintain it, then increasing the e-flow released at the dam site will need to be carefully considered. The potential need to increase e-flow, particularly during the shoulder season, is recognized as a factor in determining the final power potential and overall viability of the project (as required by NEC and noted during consultations).

6.3.3.5 Occasional Sediment Purging

Accumulated sediments in the desilting chambers will have to be evacuated from time to time, depending on the sedimentation rate in the Nikachhu inflow. Purging of the desilting chambers may result in occasional turbidity pulses in downstream parts of the river, depending on how this process is undertaken; however, this will be a very transient effect. This can be mitigated by undertaking sediment purging during the monsoon, when turbidity in the river is at a maximum, in any case. It is expected that temporary degradation of aquatic habitat and any disturbance of fish will be minimal, if undertaken at a time when the river has high suspended sediment loads (June-September). These additional sediments will be flushed quickly, into the Mangdechhu and then further downstream.

6.3.3.6 Risk of Dam Burst

The technical design and development of the project involves an independent dam safety assessment, which is expected to ensure the structural integrity of the dam under all conditions, including extreme events. As such, a dam burst is a very low probability event, the initial development of which can be monitored, if there are any signs of pending dam failure or flood conditions are developing rapidly. It is nevertheless a risk and the main concern is for human safety. Luckily, there are no communities within the flash flood zone downstream, along the Nikachhu, due to the very steep topography adjacent to the Nikachhu for its distance to the Mangdechhu (it is very inaccessible, for both people and livestock). A high volume flood would mostly be contained in the gorge down to the confluence with the Mangdechhu and then in the Mangdechhu itself, after a lag period. Figure 6-18 shows the area that would experience a flash flood in the event a dam burst during an extreme flooding event (based on modeling, using the scenario slope method; the original Bhucore report also used another method that provided the same results; only the scenario slope results are shown here). A warning system can be installed at regular points along the highway to notify people who may be near the river in the event of the risk of dam failure. This system can be backed up with an emergency communication system (a cascading system of phone calls that passes the warning message to all inhabitants near the river). The modeling data indicate that there are no buildings in the flooded zone until the lower reaches of the Mangdechhu (below the confluence with the Nikachhu; about 20 km from the dam site); some cultivated land would be flooded (also along the lower reaches of the Mangdechhu).

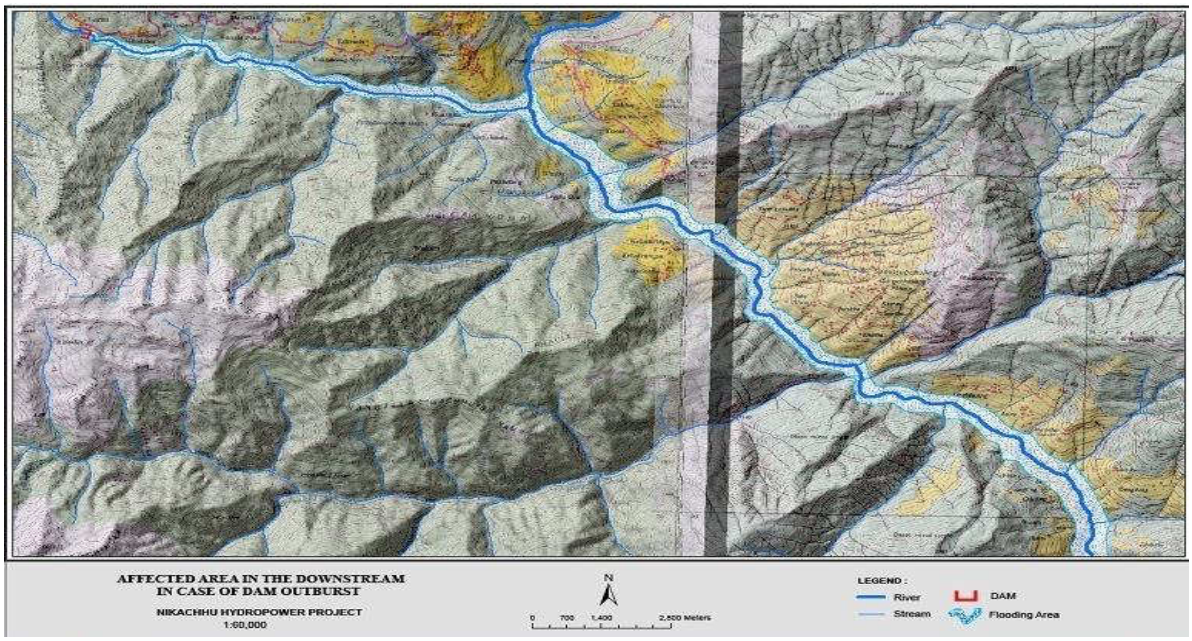


Figure 6-18: Potential flooded are during a dam burst.

A flash flood would cause scour along the river banks and a huge turbidity plume, clogged with scrub vegetation and trees; it would also damage the existing downstream aquatic habitat and flush

fish (however, only brown trout, the only fish which has been observed in the Nikachhu) into the Mangdechhu. Recovery from a flash flood would take a few years, but it would occur in time.

The incremental effect of the Nikachhu discharge going to the Mangdechhu reservoir and dam was also examined. The dam spillway of the Mangdechhu HPP has been designed to safely discharge the PMF of 6,220 m^3/s (1 in 10,000 years flood). Nikachhu during the monsoon season will discharge only 28 m^3/s into the Mangdechhu reservoir, which represents less than 0.5% of the total design flood. Therefore, the concern for safety of the Mangdechhu dam, due to discharge from Nikachhu tailrace, is minimal. In any case, during the monsoon season, the Mangdechhu reservoir will be operated at Minimum Drawdown Level, which is 16.5 m below the Full Reservoir Level.

6.3.3.7 Maintaining Cleared Right-of-Way for Transmission Line

Regular clearing of the vegetation within the right-of-way, especially near the tower foundations, will maintain stunted vegetation and reduce the quality of wildlife habitat; however, areas between the tower foundations can be allowed to grow to a height of about two meters, which will provide cover for most wildlife that need to move through the right-of-way. Local communities will likely use most of the right-of-way for farming and pasture, as it will be more accessible and suitable than before installation of the transmission line (this is a positive indirect side-effect). Negative visual aesthetics of the transmission line will persist, with regular clearing of the right-of-way; nevertheless, the alignment will remain “green”, just with lower elevation vegetation, or cultivated crops.

6.4 Overview of Cumulative Impacts

Assessment of cumulative impacts requires an understanding of the results of Nikachhu project-environment interactions being added to the possible environmental impacts of other projects and planned development in the Trongsa area. What is known at the moment includes the completion and operation of the Mangdechhu hydropower project. Other development initiatives (for example, mines, infrastructure, or changes in National Park status, or changes in agriculture and forestry) in the Trongsa have not been defined. The understanding for the Nikachhu project, then, is that its catchment area will remain more or less as it is now (mostly forested) and, subject to variations in annual and seasonal rainfall amounts (depending on climate change in this sub-region – see the separate analysis), the project will be able to operate in a predictable and stable manner, taking up less than 1% of the local area on a permanent basis, being almost invisible in terms of infrastructure, discharging to the Mangdechhu reservoir, maintaining a minimum environmental flow in the Nikachhu down to the confluence with the Mangdechhu, and not imposing any large-scale mitigation measures that will change the biological and socio-economic activities and uses in the project area.

The cumulative impact of the Nikachhu project, when associated with the Mangdechhu project, is an increment in discharge (Nikachhu water going into the reservoir above the Mangdechhu diversion dam) for increased power potential in the Mangdechhu project, and reduced discharge of river water at the confluence of the Nikachhu and Mangdechhu (notably in the lean season). However, the combined Nikachhu and Mangdechhu discharge will re-enter the Mangdechhu further downstream, coming from the tailrace of the Mangdechhu project. At this point, the discharge in the Mangdechhu will be just about similar to the natural discharge that will have occurred previously without any diversions on the Nikachhu and the Mangdechhu. The main cumulative impact of the Nikachhu project, then, is further reduced discharge in the Mangdechhu between the confluence with the Nikachhu and the point where the tailrace from the Mangdechhu project re-enters the Mangdechhu. The Mangdechhu project e-flow is 1.5 m^3/s, which is 8% of average lean season flow (December-March, at the Mangdechhu dam site). In the lean season, the Nikachhu discharge is about 25% of the discharge of the Mangdechhu; therefore, from the confluence of the two rivers to a point near Yurmo (about 6-7 km downstream from the confluence, where the Mangdechhu tailrace will discharge), the lean season discharge, during operation of both systems, will be about 10.5% of the combined lean season flow (Mangdechhu and Nikachhu, which is 24 m^3/s December to March), plus the increasing increments in discharge from about 7 tributaries on the Mangdechhu before the Mangdechhu tailrace discussed in detail in Section 6.3.3.3.

The potential for cumulative impacts can also be examined with a watershed perspective, which helps put the proposed Nikachhu project into an appropriate national area and sub-basin scale. With a catchment area of 373 km^2, the Nikachhu watershed comprises less than 25% of the Mangdechhu catchment (which is defined as sub-basin 14 in Basin #3 in Bhutan in the Water Resources Management Plan and Power System Master Plan),[10] and only about 0.9% of the total area of Bhutan. It therefore does not have much hydrological influence on the sub-basin and the whole water budget of the country. Furthermore, only about 2% of all the available water in the lean season in the Mangdechhu sub-basin is used for other purposes (mostly upper small tributary irrigation), and this is expected to remain so for the foreseeable future,[10] so hydropower water abstraction and re-entry of tailrace water within the sub-basin will not create any water use conflicts (both the Mangdechhu and Nikachhu hydropower projects, as run-of-river projects, will have water abstraction from their respective rivers and re-entry within the Mangdechhu). Regardless of these negligible watershed impacts and any expected downstream cumulative effects, the project has accommodated a pre-emptive Catchment Management Plan (for the immediate Nikachhu area

[10] Department of Energy, Ministry of Trade and Industry, Royal Government of Bhutan. 2003. Water Resources Management Plan and Power System Master Plan. Thimphu.

above the dam site), which will help preserve the current forest integrity and water quality in the Nikachhu catchment area (see Section 1.2.3.6 of the EMP).

The Nikachhu project will produce renewable power that will offset a very significant amount of carbon dioxide emissions in the future, which would be due to burning of wood (for heat/cooking) and burning of fossil fuels for electricity generation. This is a very significant positive cumulative impact of the Nikachhu project.

There is a further concern for possible uncontrolled development occurring along any permanent access roads. However, population density in the Trongsa area is very low, so pressure to expand settlements along new roads is minimal (there is already very little development along existing roads) and, in any case, all proposals for new buildings and facilities must be reviewed by the Trongsa District authorities.

6.5 Conclusions Regarding Potential Impacts, Mitigation, and Project Acceptability

The impact assessment noted in Sections 6.1 – 6.4 indicates that there are no significant negative environmental and socio-economic impacts associated with the proposed Nikachhu project that cannot be mitigated to negligible or acceptable levels. All significant issues were screened out during the consideration of alternative locations. Furthermore, the relatively small scale of the project footprint in an immediate project area of about 254 acres (101.6 ha) in an area that has an expanse of similar habitat in all directions, and which does not support unique or critically vulnerable flora and fauna, is the main factor in keeping environmental and socio-economic impacts at an acceptable and manageable level. Experience with similar projects in Bhutan indicates that the temporary negative consequences of construction work can be managed with “best practice” measures to minimize sediment mobilization, reduce noise and air quality issues, and contain waste, so that there is no degradation of terrestrial and aquatic habitats. Trees that have to be cut will be replaced, and land that is required for the project will be compensated. Impingement on the buffer area of the National Park will have no ecological significance, wildlife in the area will still have access to wide swaths of natural habitat for refuge and movement, the very limited fish population in the river will still exist above and below the diversion dam (no fish migration is evident in the Nikachhu, due to waterfalls), and minimum environmental flow will maintain an adequate aquatic habitat in the downstream section.

There is full local community acceptance of the project (very few families are directly impacted by the project, and no relocation is required). The project will bring significant power service reliability to Bhutan and local and national economic benefits, as well as significant greenhouse gas emission reductions.

All required mitigation measures and respective monitoring of their performance are documented in Part 2 (Environmental Management Plan); this EMP will become the *modus operandi* for the project, ensuring that predicted impacts are well-managed, and that accountability for mitigation performance is in place.

Given the observations and conclusions from the impact assessment process documented above, the project appears to be acceptable for implementation, as designed, according to Royal Government of Bhutan and ADB standards.

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