APPENDIX H

ATTACHMENT 3

TERRESTRIAL ECOLOGY

MUNDA DAM MULTIPURPOSE PROJECT
ENVIRONMENTAL SURVEY

Attachment 3: Terrestrial Ecology

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1. Introduction

1.1 Study Objectives and Scope of Work

This ecological study was conducted for Japan International Cooperation Agency (JICA) as part of an environmental survey for the Munda Dam Multipurpose Project. The survey findings will be used by JICA in its environmental impact assessment (EIA) of the project.

The study area for this ecological survey consisted of the proposed dam and reservoir area, the command areas of the proposed canals (on the left and right bank of the Swat River), and the riparian zones downstream of the proposed dam. Primary data on plant communities, animal communities, soil and water was collected from different parts of the study area.

This ecological study was conducted primarily to collect a baseline inventory of the study area's flora and fauna, soil, and surface and groundwater hydrology. Information collected on the area's surface and groundwater hydrology included data on siltation, water quality, river discharge, expected changes in discharge downstream of the dam site, and groundwater quality. An assessment of the area's soils, soil erosion, contamination, and salinity problems was carried out. Possible impacts of water diversions on the area's soils, the possibility of reservoir water contamination, and post-project contamination of water in the downstream reach, eutrophication, and changes in water temperature were also evaluated.

1.2 Approach and Methodology

1.2.1 Flora

Data collection was undertaken in the dam site, reservoir area, and command area in October, November, December and January, 1998 and 1999. A review of relevant literature on the area was also undertaken.

For the floral investigation, quadrats (sample plots) of equal size (100 m^2) were selected randomly throughout the study area according to the Braun-Blanquet method of ecological sampling. The quadrats were laid out at random sites near the dam site, reservoir area, and command area, at different slope aspects and elevations.

In all, 45 quadrates were sampled during this investigation. The information collected was then used to identify different vegetation communities in the study area. Photographs of the different vegetation communities were taken at various locations. Using data on the plant species present, the ecological value of the surveyed communities was assessed at the site, and evaluated further during data analysis and the literature review.

For every community, each species was categorized on the basis of coverage and abundance in one of the following six classes:

- Sparsely or very sparsely present, small cover +
- Plentiful, but small cover I
- Covering at least 5-25% of the area II
- Covering 25-50% of the area III
- Covering 50-75% of the area IV
- Covering more than 75% of the area V

The frequency of all species documented in the area was determined by calculating the percentage chance of occurrence of the species within the quadrats. This was calculated as follows:

$$\frac{\text{Quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

'Constancy' is the persistent occurrence of a species within the quadrats. On the basis of the calculated frequency values, the plant species were categorized in the following constancy classes:

- Occurring in 1-20% of the quadrats I
- Occurring in 20-40% of the quadrats II
- Occurring in 40-60% of the quadrats III
- Occurring in 60-80% of the quadrats IV
- Occurring in 80-100% of the quadrats V

1.2.2 Fauna

Fauna studies were undertaken using the field techniques described below.

- Bird surveys were conducted along line transects (Bibby et al., 1993) as well as through fixed point counts. Line transects were laid early in the morning, and surveys along them were conducted by slowly walking along a straight line, and documenting details about the birds seen or heard. These included identification of the bird, location, habitat type, coordinates, and the time of day.
- Small mammal surveys were conducted by scanning mammal habitats, and sampling their communities using such techniques as

'Sherman' live traps. The traps were placed in a grid measuring 10 m by 10 m, and were left overnight in all the major habitat types within the reservoir and dam site areas.

- Surveys of large animals were carried out by scanning their habitats and documenting any direct or indirect evidence found, i.e., actual sightings, active burrows, dens, dropping, tracks, etc.
- Local communities and hunters were also interviewed to record local knowledge about wildlife in the area.

1.2.3 Water and Soil

In all, 13 water samples were collected from the reservoir and dam areas to determine the physical and chemical properties of the water. Soil samples were collected from different depths in the reservoir area, the dam site, and the right and left bank command areas. Some of the physical characteristics of the soil, such as texture and color, were noted on the spot. A total of 80 soil samples were collected, and their physical characteristics noted. The chemical characteristics of 9 samples were analyzed in a laboratory.

Chemical analyses of soil and water samples were carried out at Hagler Bailly Pakistan's environmental laboratory in Islamabad.

1.3 Organization of this Report

Section 2 of this report describes the flora and fauna of the study area. Section 3 describes the area's hydrology, its climate, surface and groundwater hydrology, sedimentation, and reservoir operation. Section 4 discusses the area's soil and water quality. Finally, Section 5 presents the study conclusions, and recommends measures for the conservation and restoration of the area's ecological resources.

2. Flora and Fauna

The study area is located in the southern part of the Swat Valley, where the Swat River passes through a narrow gorge. It is characterized by low hills that rise 600-900 m above sea level.

The study area is located within a belt of tribal areas. Because of its particular sociocultural traditions, it was inaccessible to outsiders for a long time. Detailed scientific, ecological, and taxonomic studies have not been carried out here in the past, and no data is available for comparison with the current survey.

2.1 Flora

2.1.1 Overview

Since the local people depend upon the area's natural resources for survival, most of the original forests have almost completely vanished or been altered. More than 90 percent of the area is covered by *Dodonea viscosa* (snatha) and *Justica adhatoda* (bhaikar), species that colonize heavily disturbed areas, such as those subjected to overgrazing. There is heavy grazing pressure in the low hills around the study area, where palatable plant species have almost completely disappeared, and the smaller livestock is forced to feed on unpalatable species, such as snatha, bhaikar, *Saccharun*, and *Cymbopogon*.

Very few of the original plant communities remain and they are generally very small. Undisturbed pockets of vegetation in graveyards and on steep, relatively inaccessible slopes give an indication of the area's original flora. There are still some isolated, scattered patches of *Acacia nilotica* (kikar), *Acacia modesta* (phulai) and *Olea ferruginea* (wild olive).

Phytosociological sampling has been carried out in these small patches of original vegetation. They are mostly located along the lower slopes of the Swat River in areas likely to be affected by inundation. They cover less than 5 percent of the slopes in the study area; the remaining vegetation cover is dominated by *Dodonea*, *Justicia*, *Rhazya*, *Cymbopogon*, and *Saccharum*.

Hills in the study area are generally 600 to 900 m high, with moderate slopes and shallow soil cover. The average vegetation cover on their slopes ranges from 40 to 60 percent, depending on the bedrock, and exposure to the sun. The area does not receive snowfall because of its low altitude, and summer temperatures are high. It appears that most of the hills were covered by scrub-type vegetation, such as kikar, phulai, and olive, in the past. On some of the higher hills, a few chir pine (*Pinus roxburghii*) trees can still be seen, but they are greatly endangered.

2.1.2 Vegetation Communities

For the phytosociological inventory and identification of habitat types, 45 quadrats were laid out at different locations in the study area. Samples were taken from all the observed communities and their species composition was determined. In all, 7 plant communities were identified and sampled in the dam site area, 5 in the reservoir area, and 3 in the command area. The composition, characteristics, and potential values of these communities are discussed below. (In addition, Appendix A presents a set of photographs of the study area, showing some vegetation communities.)

Communities in the Dam Site

Rhazya Stricta

This is one of the most common plant communities in the environmentally degraded parts of the project area. Vegetation cover is generally less than 5 percent of the ground area, and species diversity low.

The community is found on light yellowish brown soils (The Munsell color chart value is 10 YR6/4), which have a silty to gravelly loam texture, and a massive structure with fine pores.1 The soils are slightly calcareous and non-saline, and contain a few medium adventitious roots.

The *Rhazya Stricta* community is home to different wildlife species, including the *chukor*, black partridge, gray partridge, see-see partridge, jungle cat, larger rat-tailed bat, gray mongoose, red lynx, stone martin, and shrew. There are many medicinal plants in this habitat type. **Exhibit B.1 in Appendix B** gives more details of this community, such as the presence, abundance, frequency, and constancy class of different plant species.

Acacia Nilotica

The *Acacia Nilotica* community grows in non-saline piedmont alluvium. The soils are brown in color (7.5 YR 5/4), massive, contain secondary and adventitious roots to a depth of 20 cm, and are calcareous in nature. **Exhibit B.2 in Appendix B** gives more details.

This community contains some of the area's original scrub vegetation, which has been considerably depleted because of selective grazing and cutting. Many invasive species, such as *Rhazya stricta, Withania coagulans,* and *Solanum surattense,* now occupy areas where the original vegetation has been cleared.

The *Acacia Nilotica* community provides suitable habit for such birds as the *chukor*, red jungle fowl, yellow-throated martin, common babbler, white-cheeked bulbul, and the little brown dove. Some mammals found in this community are the Indian hare, jungle cat, house mouse, Indian bush rat, Indian gerbil, and the Indian desert *jird.*

Zizyphus Nummalaria - Acacia Nilotica

Acacia nilotica trees are sometimes found together with other species, such as *Zizyphus nummularia* and *Acacia modesta,* especially in the *Zizyphus Nummalaria-Acacia Nilotica* community. Ground vegetation in this community is very sparse, and overgrazing has led to an increase in the growth of non-palatable plant species.

Soils in this community are yellowish brown in color (10 YR5/4), have a silty loam texture with a few fine tubular pores, massive, and are moderately calcareous and non-saline.

This community provides habit for a variety of animals. **Exhibit B.3 in Appendix B** gives further details.

Justicia Adhatoda

The *Justicia adhatoda* community is one of the most common communities in the study area and is spread over large parts of the project area. It consists of numerous species besides the *Justicia adhatoda,* such as *Zizyphus nummularia, Aerua javanica, Otostegia limbata, Segeretia theezans,* and *Periploca aphylla.*

Soils in this community are dark brown (10 YR 3/4), with a sandy loam texture, a massive structure, and have a fine porous stratification. Secondary and tertiary roots are present in the surface layer to a depth of 30 cm. The soil is non-saline and moderately calcareous.

This habitat type houses some bird species, such as the black partridge, gray partridge, common babbler, and the little brown dove. Mammals include the jungle cat, caracal, soft furred field rat, lowland hedgehog, stone martin, hill fox, and the cape hare.

Exhibit B.4 in Appendix B gives further details.

Chrysopogon – Adhatoda

Chrysopogon is a palatable grass species, which has been considerably depleted by heavy grazing. It is being replaced in this community by non-palatable species such as *Justicia adhatoda* and *Dodonaea viscosa.* Sparsely scattered trees and shrubs such as *Acacia modesta, Periploca aphylla* and *Themeda anathera* can also be found in this community.

The soils are generally brown to dark brown (10 YR 4/3), with a sandy clay loam texture, a massive structure, and many roots and pores present. The soils are moderately calcareous and non-saline.

Wildlife species found in this community include the *Cuculus varius, Anthus similus, Pycnonotus leucogenys, Carduelis spinoides, Pitta brachyura, Pomatorhinus erythrogenys* and *Turdus boulboul.*

Control on grazing would reduce the pressure on palatable grass species in this community, which would then grow more abundantly, ensuring a sustainable supply of fodder for animals. Grazing control will require use of alternative sources of fodder, and scientific range management practices and livestock herding.

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1 Soils with a massive structure (also known as structureless) are *not* arranged into aggregates, are compact, and tightly bound.

Exhibit B.5 in Appendix B gives further details of this community.

Aerua Pseudotomentosa

Aerua pseudotomentosa is a non-palatable species spreading in communities that are being subjected to heavy grazing and woodcutting. Some shrubs in this community, such as *Acacia modesta, Segeretia* and *Zizyphus*, are part of the area's original vegetation.

Soils are brown to dark brown, with a sandy loam texture, massive structure, and fine roots. They are non-saline and slightly calcareous.

Wildlife found in this community includes *Bucanetes githogineus, Oenanthe alboniger, Euodice malabarica, Laniks excubitor, Emberiza striolata, Eremopterix grisea,* and *Coccothraustes coccothraustes.*

Exhibit B.6 in Appendix B gives more details.

Themeda Anathera

Themeda anathera is a palatable fodder species that is generally found along with *Chyrsopogon aucheri.* This community has great value as a source of food for both livestock and wildlife. In addition, its comparatively greater vegetation cover protects soils and reduces erosion.

Typical wildlife species found here include the yellow eyed babbler, long-tailed grass warbler, jungle sparrow, fishing cat, jungle cat, wild boar, small Indian civet, and black partridge. Some important summer breeding visitors include the *Francolinus francolinus, Cuculus varius, Glaucidium cuculoides, Caprimulgus mucrunas, Prinia hodgsonii, Rihipidura albicollis.* Winter visitors include the *Prunella strophiata, Phoenicurus erythrogaster, Turdus boulboul,* and the *Carduelis spinoides.*

The soils mainly consist of piedmont alluvium, and are dark yellowish brown (10 YR 4/4). They are non-saline, moderately calcareous, have a gravelly loam texture, are 20 percent gravel by volume, contain secondary and adventitious roots, and have very fine pores.

Exhibit B.7 in Appendix B gives more details.

Communities in the Reservoir Area

Saccharum – Plectranthes

This community contains some important palatable grass species, and can be used by rotational grazing and deferred grazing systems. Common bird species found here include the *Equila napus, Gallinula chloropus, Bubo bubo, Cuculus canarus, Prinia criniger, Chrysonna sinensis, Phylloscopus gresiolus.* Mammals include the hill fox, greater hedgehog, caracal, and Indian gray mongoose.

The soils are generally dark brown (10 YR 4/3), have a gravelly loam texture, are 10 percent gravel by volume, have a massive structure, contain fine roots, and are moderately calcareous and non-saline.

Exhibit B.8 in Appendix B gives more details.

Dodonaea Viscosa

Dodonaea viscosa is used as firewood, and is also a good soil binding species. This community also contains the *Adhatoda vasica,* a species that is obnoxious, but has medicinal value. It also provides good cover and shelter for wildlife.

Soils in this community are brown to dark brown (10 YR 4/2), have a gravelly loam texture, a sub-angular blocky structure, contain fine and medium roots, and are slightly calcareous and non-saline.

Exhibit B.9 in Appendix B gives more details about this community.

Olea – Dodonaea – Adhatoda

This community is found on very steep slopes (around 90 percent), where soils are subject to severe gully erosion. It consists of plants such as *Olea cuspidata,* which are used for firewood and for fodder to enhance milk production in animals. The *Dodonaea viscosa* plants are also used as firewood. Both species are good soil binders and reduce erosion. Some medicinal plants, such as *Withania coagulense, Adhatoda vasica, Fagonia cretica,* are also found in this community.

The soils are dark grayish brown (10 YR 4/2), have faint but distinct mottles, a sandy silty loam texture, a moderate medium to sub-angular blocky structure, contain many thick and fine roots, and have fine pores. The parent rock is moderately calcareous and non-saline.

Exhibit B.10 in Appendix B gives further details of this community.

Dodonaea – Cymbopogon

This community is also a good soil binder and reduces soil erosion. The vegetation provides good cover for wildlife, and comprises of a number of palatable plant species.

The soils are generally a dark coffee brown color (10 YR 4/3), with a silty clay loam texture, a weak, coarse, and medium sub-angular blocky structure. The soil is porous, moderately calcareous, and non-saline and has medium and fine roots present in it.

Exhibit B.11 in Appendix B gives more details about this community.

Monotheca – Dodonaea

This community is located close to the Swat River. In it, the *Nerium odorum* (kaner), *Vitex negundo*, *Cymbopogon jwarancusa* (sargare), *Adhatoda vesica* (bekar), *Cannabis sativa* (bhang), *Chenopodium botrys* (bathu) species are quite abundant.

Common wildlife species in this community are the black partridge, gray partridge, *chukor*, white-cheeked bulbul, brown hill warbler, leaf warbler, and rock bunting.

The soils are a light olive brown color (10 YR 6/4), with a few gray and yellowish mottles. They have a sandy silty loam texture, are massive, have secondary and tertiary roots and very fine pores, and are non-saline and moderately calcareous.

Exhibit B.12 in Appendix B gives further details of this community.

Communities in the Canal Command Areas

Acacia Modesta – Cymbopogon Jwarancusa

Different types of palatable grasses grow in this community. The bird species found in this habitat type include the common babbler, white-throated *munia*, black partridge, gray partridge, see-see partridge, sand grouse, little brown dove, and Indian roller. Mammals include the soft furred rat, Indian crested porcupine, desert cat, jackal, hare, fox, hedgehog and Indian pangolin.

Soils in this community are reddish brown or dark brown (10 YR 4/3); have a sandy loam texture; are massive, breaking into a granular structure; contain fine roots; and have fine tubular pores. They are moderately calcareous and non-saline. Below the surface, the soil moisture content is high.

Exhibit B.13 in Appendix B gives further details about this community.

Butea – Frondosa

This community has great potential as a source of medicinal plants. It is an important habitat for the lac insect (*Laccifer lacca*). Plants of medicinal value include the *Adhatoda vasica* (bekar), *Datura alba*, *Fagonia arabica*, *Peganum harmala* (harmal), and the *Plectranthus rugosus*.

The soils are brown to light olive brown in color (25 YR 5/4), deep, and have a sandy clay loam texture. A lot of moisture is present below the soil surface, and soil crumbs break into a weak, coarse, sub-angular blocky structure. The soils contain a few roots and fine pores. They are moderately calcareous and saline.

Exhibit B.14 in Appendix B gives further details.

Plectranthus – Dodonaea – Olea

This community contains a number of plants that provide food and shelter for both livestock and wildlife.

Soils in which this community grows are dark yellowish brown (10 YR 4/4), and have a sandy clay loam texture. They are massive, commonly have secondary and tertiary roots present, have fine and very fine pores, and are non-saline and moderately calcareous.

Exhibit B.15 in Appendix B gives more information about this community.

2.2 Fauna

The study area provides habitat for a variety of animals. A large number of mammals, birds, reptiles, fish, and micro and macroinvertebrates have been reported, including 17 reptile species, 2 amphibian species, 37 mammal species and 119 bird species (Roberts, 1997, 1991 and 1992; Minton, 1966; PMNH, 1997; Mirza, 1973 and 1976).

Of the 37 mammal species reported in the study area, over 70 percent are abundant or common. Only nine species are reported as rare.2 These are the house shrew, pygmy shrew, common noctule, Himalayan pipistrelle, caracal, leopard, Kabuli *markhor*, *urial* and *rhesus* monkey. It was found during this survey that excessive hunting has made the leopard, *urial* and Kabuli *markhor* locally extinct. Monkey populations are also declining because of persecution by local villagers. The *rhesus* monkey is presently still quite abundant in a few pockets of the study area and, despite shooting and trapping by local villagers, has been able to coexist with people, even in heavily settled hill regions. Because it digs up ripening maize cob and potatoes, local villagers lose no opportunity to kill it. Young monkeys, secured after the mother has been shot, can easily be sold as pets to visitors from the plains in summer, or to itinerant gypsies who earn money from performing bears and monkeys.

Asiatic jackals, foxes, bats, gerbils, rats, girds, mice, porcupines and squirrels are common in the study area. During the present study, porcupine spines and hedgehog skins were often found, and droppings of the desert hare, jackal and fox were frequently observed. However, during small mammal sampling, only one rodent was trapped and identified as a mouse-like hamster, *Calomyscus bailwardi*. The Kashmir fox was also frequently sighted in the study area.

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2 **Rare:** Taxa with small population that are not presently endangered or vulnerable, but are at risk. These taxa are usually localized within restricted geographical area or habitats or are thinly scattered over a more extensive range.

The study area is also inhabited by a large number of migratory and resident birds. More than 100 species are reported in the area in 11 orders and 40 families. Except for 7 species that have been reported as rare/scarce, all the birds are common and are frequently observed in the area. There are no endemic or threatened3 bird species. The rare species are the bearded vulture, Bonnelli's eagle, eurasian kestrel, merlin, Saker falcon, peregrine and red-capped falcon. The more common birds observed during the survey include the blue rock thrush, plumbious redstart, riverchat, goldnets redstart, red breasted flycatcher, blackbird, desert lark, pied wheatear, white throat, red-vented bulbul, white-cheeked bulbul, house bunting, common swallow, white-eyed buzzard, great gray tit, scrub streaked prinia, see-see partridge, jungle babbler, black redstart, rock bunting, rock pigeon, spotted munia, crested lark, sand plover and *chukor* partridge. Excessive hunting by the local people is depleting the population of partridges in the area.

The study area is also a good habitat for reptiles and amphibians. Common reptiles include the Persian gecko, spotted Indian house gecko, Indian garden lizard, Kashmir rock agama, earless skink, Himalayan ground skink, Punjab snake-eyed lacerta, Indian monitor lizard, cliff racer, mountain racer, Persian diadem snake, dhaman or rat snake, dark headed dwarf racer, checkered keelback, Indian krait and oxus cobra. Two amphibian species that were expected to be found, but were not seen during field surveys, are the European green toad and the skittering frog. A snake, *Eehis carinatus*, of the *Viperidae* family and a tadpole of the *Rallidae* family (Amphibia) were collected and preserved during field surveys.

Published information on the area lists 7 rare bird species (**Exhibit 2.1**), 2 threatened mammal species (**Exhibit 2.2**), 7 rare mammal species (**Exhibit 2.3**), 12 rare reptile species (**Exhibit 2.4**), and 2 rare amphibian species (**Exhibit 2.5**).

3. Hydrological Studies

This section is based on JICA's project prefeasibility report and Progress Report (1). Other sources of information include the Pakistan Meteorological Service (PMS), the Surface Water Hydrology Project (SWHP) of WAPDA and the Irrigation Department, NWFP.

3 **Threatened:** Species that are in one of the following categories: endangered, vulnerable, and rare. Some species are considered threatened when there is not enough information to say which of these three categories are appropriate.

3.1 Climate

Classification

Various meteorologists have developed classifications to describe local climatic features in Pakistan.

Shamshad (1956) has classified the climate of Pakistan on the basis of characteristic seasons found in the country. Taking into account topography, proximity to the sea, rainfall, temperature, and winds, he has defined eleven climatic zones for Pakistan. Under his scheme, the climate of the study area is classified as an "Extratropical quadruple season type." The area is further divided into arid highlands, semi-arid highlands, mild-climate highlands, and humid highlands.

The study area falls in the semi-arid highland type. The main features of this zone are rainfall between 254 mm and 508 mm, a mean minimum temperature of 0°C or less, and a mean maximum temperature not exceeding 37°C.

Description of Seasons

There are four seasons in Pakistan:

- Winter (December to March);
- Summer (April to June);
- Monsoon (July to August); and
- Post-Monsoon Summer (September to November).

The study area is affected by all four seasons, which are defined mainly on the basis of temperature and the changes associated with the southwest monsoon, a wind system that causes heavy rainfall over most of the Indian subcontinent.

Within Pakistan, considerable variation is found in temperature and the magnitude of monsoonal changes. Thus, the specific characteristics and duration of seasons depend on geographical location.

Temperature and Rainfall

There are two rainfall seasons in the study area—July-August and February-March. The maximum of mean relative humidity is highest in September (93 percent), and lowest in June (24 percent). The maximum mean monthly temperature is highest in June and lowest in January.

The climate varies considerably over the Swat River catchment area. In the upper basin of the Swat River, winter temperatures reach freezing levels between November and March. Snow melting temperatures occur between April and September. In the lower basin, temperatures generally stay below freezing levels. The Swat River flows perennially, the flow being generated from snowmelt and rainfall at higher

altitudes. In the lower basin, winter rainfall is generally less intense than the summer monsoon rainfall, whereas in the upper basin, winter rainfall is more intense than summer rainfall.

The total catchment area of Swat River at the proposed Munda dam site is 13,650 km². A map of the river's catchment area is shown in Exhibit 3.1. According to the normal isohyet map prepared by the Pakistan Meteorological Service in 1971, the annual rainfall within the catchment area varies locally from 380 mm to 1,270 mm and the average annual rainfall for the entire catchment area is 810 mm.

There are 8 rain gauging stations along Swat River. No station exists on the Pinjkora River, which covers approximately 40 percent of the catchment area of the proposed Munda Dam. The monthly rainfall data for major gauging stations in and around the study area, such as Kalam, Charbagh, Amandara, Malakand, Abazai, Utmanzai and Mardan, are presented in Appendix C.

3.2 Water Discharge Data

The discharge of Swat River is gauged at Kalam in the extreme north, at Chakdara (almost 80 km upstream of the proposed dam site), and at the existing Munda Headworks, a few kilometers downstream of the proposed dam. These stations are shown in Exhibit 3.1. Mean monthly discharge data from these stations have been presented in Appendix D.

3.3 Water Availability

The Hydrology Division, Irrigation Department, Peshawar, has a river gauge about 500 m upstream of the Munda Headworks. Arrangements for measurement of water velocity are not available at this station. Based on observations at the site, it was concluded that flow records maintained at the Munda Headworks are not accurate. It is essential that a regional analysis for water availability in the proposed Munda dam site be carried out.

Diversions on the Upper Swat Canal at Amandara Headworks and the diversions made by the local farmers draw 200 cusecs from the river reach between Amandara and Munda. This should be subtracted from the synthesized flow of Swat River. The annual average water availability then comes to 6.13 million acre-feet (MAF), based upon annual average water discharge of Swat River at Munda (Exhibit D.3).

Additional diversions are likely to be made by farmers upstream of the Swat River at Chakdara and on the Pinjkora River. These are shown in Exhibits E.1 and E.2 in Appendix E. These are expected to lower the average annual water availability at Munda to around 6 MAF, i.e., by almost a 2 percent.

3.4 Suspended Sediment

The suspended sediment data for the years 1964, 1965, 1969, 1970, 1971, 1972 and 1973 are available in the published report of the Hydrology Division, Irrigation Department Peshawar. The data for 1971 at Munda and 1995 at Chakdara are presented in Exhibits E.3 and E.4, respectively.

Suspended sediment data available in a publication prepared by SWHP (*Sediment Appraisal of Pakistan Rivers*, July 1987) includes data for Kalam, Chakdara, Warsak and Nowshera (Exhibit E.5). Suspended sediment data for these stations are summarized in Exhibit E.6.

The project's prefeasibility report estimated that the river's sediment yield at the proposed dam site is 230-240 ton/km². Assuming that the bed load is approximately 20 percent of suspended load (12 percent of sediment load with a safety factor of 1.5), the total sediment load is estimated at 290 ton/km².

There is another method to estimate the annual sedimentation using the available data. The sediment yields of the Kabul River at Warsak (upstream of the river's confluence with the Swat River) and at Nowshera (downstream of the river's confluence with the Swat River) are shown in Exhibit E.6. By calculating the sediment yield of the residual area between the catchment areas of the Kabul River at Nowshera (88,630 km²) and at Warsak (67,339 km²), the sediment yield of the Swat River at the proposed dam site can be estimated.

The estimated sediment yield in the residual area is 930 tons/km².4 Since the Swat River's catchment area at the proposed dam site is about 65 percent of the residual area, the sediment yield at Munda can be assumed at about 600 tons/km².

3.5 Bed Load

As discussed in Section 3.4 above, the Swat River's sediment yield at Munda has been estimated to be 230 to 240 tons/km². With a catchment area of 13,650 km², the annual average suspended sediment load at Munda is 3.28 million tons.5 A conservative estimate of bed load is 12 percent of the suspended sediment load, which comes to 0.39 million tons. It should be noted, however, that the Swat River has a steep bed gradient, which means the river flows at high velocities during high flow. It is therefore necessary to add a safety margin by multiplying the estimated bed load by 1.5. After doing so, the bed load for the Swat River at the proposed Munda Dam site comes to 0.59 million tons.

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4 (35.57 million tons – 15.77 million tons)/(88,630 km² – 67,339 km²)

5 Higher value of sediment yield has been considered.

The total sediment load can be estimated by adding the suspended load (3.28 million tons per year) to the bed load (0.59 million tons per year). Thus, 3.87 million tons of sediment passes through the proposed Munda Dam site annually.

3.6 Average Annual Sediment Inflow

Based on the fresh suspended sediment density of 915 kg/m^3, the average annual suspended sediment load (3.28 million tons) is estimated at 3.58×10^6 m^3 (2,903 acre-ft). The bed load (0.59 million tons), with a density of 1,765.5 kg/m^3, amounts to 0.33×10^6 m^3 (271 acre-feet). Thus, the annual average sediment inflow to the Munda dam reservoir is estimated as 3.91×10^6 m^3 (3,171 acre-feet).

3.7 Dead Storage Requirements

With the proposed maximum reservoir level of 541.6 m above mean sea level, it is estimated that the reservoir will have a gross storage capacity of 931×10^6 m^3 (Exhibit 1.3). From sedimentation data (Section 3.6 above), it has been estimated that 391 m^3 of sediment will enter the reservoir after 100 years of reservoir operation. After deducting the quantity of sediment which will flow out of the reservoir along with the water, it has been estimated that 308 m^3 of sediment will be deposited in the reservoir after 100 years. The sediment quantity deposited in the reservoir after this period constitutes the dead storage of the reservoir.

After this period, the reservoir's storage capacity will be reduced to 623 m^3, but it will still be operating at full electricity generating capacity since the deposited sediment will only take up the dead storage volume. Thereafter, the reservoir's live storage capacity will start declining, and the electricity generation capacity will decrease accordingly.

If the dam height is reduced, the reservoir's storage capacity will also decrease, and the number of years that it can operate at full electricity generating capacity will decrease proportionally.

3.8 Reservoir Operation Studies

Reservoir operation studies need to include the reservoir's release patterns, which should conform to downstream water requirements, which consist of:

1. Water required for the Lower Swat Canal (LSC) and Daoba Canal, both of which are located downstream of the proposed dam site;
2. Water for the additional command areas both on the left and right banks of the Swat River, which are to be irrigated by the Munda Dam;
3. Requirements of the local people who divert water directly from the Swat River (about 300 cusecs) downstream of Munda Headworks.

Details of all these requirements, together with the average river inflow to Munda, are listed in Exhibit E.7 in Appendix E.

4. Soil and Water Inventory

4.1 Soil

4.1.1 General Characteristics

The soils in the study area generally comprise of piedmont alluvium and are of mixed mineralogical composition and variable texture. The texture is mostly loamy, but varies from fine sandy loam to silty clay loam. The color ranges from brown to dark brown and dark yellowish brown. The structure of the surface soil is mostly massive, but the subsoil has a weak to moderate, medium to coarse sub-angular blocky structure.

4.1.2 Soil Analysis

For this ecological survey, 80 soil samples were collected at different depths from the right and left bank command area. The depths were 0 to 20-25 cm and 20 to 90 cm. The samples were dug up using soil auger and were stored in plastic bags. Certain physical characteristics like texture and color were noted on the spot. The color was determined using a Munsell color chart, and the texture, by the 'finger touch' method.

Ten samples were selected for soil analysis, six from the left bank of the command area, and four from the right bank. All ten samples were analyzed in Hagler Bailly Pakistan's environmental laboratory in Islamabad. The analysis data are shown in the Exhibits 4.1 and 4.2.

All the soils of the study area were found to be non-saline, non-sodic, and slightly to moderately calcareous. The pH varies from 6.30 to 7.28. The organic matter content varies from 0.25 percent to 0.83 percent, and the phosphorus content, varying from 3.20 to 3.80 mg/kg, is quite low.

Detailed soil reports in the Munda Dam project prefeasibility report give results of surface samples and seven pit samples. The investigations showed that soils in different parts of the study area are distinguished mainly by texture, gravel nature, and relief/topography. On the basis of these criteria, seven soil zones were identified and mapped in the prefeasibility report of the study area.

It was found that 29.3 percent of the area is level, and has deep loamy and clayey soils, 35.5 percent has undulating topography and is covered by loamy soils with varying levels of gravel, 27.0 percent consists of highlying gravelly ridges, and the remaining 8.2 percent consists of hill torrents and settlements.

In the left bank command area, pH ranges from 6.30 to 7.02, organic matter varies from 0.41 percent to 0.46 percent, and organic carbon ranges from 0.23 percent to 0.47 percent. The nitrate content ranges from 13.0 mg/kg to 15.0 mg/kg. Phosphorus varies from 3.20 mg/kg to 3.80 mg/kg. Sulfur contents are below 1.0 mg/kg in all the six soil samples of the left bank command area. Similarly, zinc contents range from 0.52 mg/kg to 0.72 mg/kg, respective

The right bank command area has a pH varying from 6.67 to 7.00. Organic matter varies from 0.25 percent to 0.72 percent and nitrate contents vary from 13.12 mg/kg to 14.40 mg/kg. Sulfur contents are below 1.0 mg/kg. Zinc contents vary from 0.65 mg/kg to 0.80 mg/kg.

Results of the soil analysis reveal that both the right and left bank command areas are poor in organic matter, nitrogen and phosphorus contents. Fertilizer and farmyard and green manure would have to be used in the command area to produce suitable agricultural crops.

Exhibit 4.3 describes the suitability of different crops for different soil types in the study area.

4.1.3 Land Capability Classes

The study area has been classified into different land capability classes based on the nature and magnitude of soil limitations affecting crop production potential. It is known that 40 percent of the area comprises of very good agriculture land; 24 percent, moderate agricultural land; and 27 percent can be used for forestry and range management. The remainder of the land is unsuitable for agricultural use.

According to the US Bureau of Reclamation system, the land can be divided into the following land capability classes:

- Class I arable
- Class II arable
- Class III arable
- Class IV arable

The study area's classification is described in Exhibit 4.4.

Class I Arable

About 29 percent of the study area falls under this class. The soils are generally level, very deep loamy and clayey, and have favorable surface infiltration and subsurface drainability. They have good water and nutrient holding capacity and are highly suitable for the cultivation of a wide range of crops. Vegetables and fruits are best grown on this class of land.

Class II Arable

About 11.6 percent of the study area lies in this class. This type of land can be divided further into two subclasses.

The first subclass has deep loamy soils. With the use of artificial fertilizers, green manure and farmyard manure, high crop yields can be obtained from this area.

The second subclass has gently sloping deep loamy soils comprising of 20-30 percent gravel and stones. Land leveling, gravel scrapping and the use of fertilizers on these soils would result in high crop yields.

Class III Arable

About 23.9 percent of the study area falls under this class. Again, it can be divided into two subclasses.

The first subclass has nearly level, shallow, gravelly loamy soils containing 50 to 60 percent gravel at a depth of 35 cm. Because of the gravel, water and nutrient retention are low. These soils could yield better crops than they presently do if the surface gravel was removed, split doses of fertilizer were applied, the land was lightly and frequently irrigated, and shallow-rooted crops were cultivated.

The second subclass includes gravelly loamy soils, with 50 percent gravel in the subsurface and 30 percent gravel in the surface. Their agricultural potential can be improved by removing the gravel, applying fertilizer and green manure, and cultivating shallow-rooted crops.

Class IV Arable

About 27 percent of the study area falls in this class. The soil is composed of 80-90 percent gravel. Because of the high topography and extremely stony nature of these soils, the area is unsuited for irrigated agriculture and should be utilized as rangeland or for forestry.

The remaining 8.2 percent of the study area has been classified as miscellaneous land types such as torrent beds, etc.

4.2 Water Quality

Thirteen water samples were collected from the reservoir and dam area to evaluate the quality of water in the study area. The water sampling sites and schedule are presented in Exhibit 4.5.

Water analysis for the reservoir area showed that the pH varies from 8.35 to 8.44 and the dissolved oxygen values vary from 0.1 mg/l to 4.0 mg/l. Chloride contents range from 9.78 mg/l to 17.93 mg/l. Nitrite varies from 0.06 mg/l to 0.07 mg/l. The nitrate content ranges between 0.70 mg/l and 1.10 mg/l, while phosphorus contents are 0.65 mg/l to 1.85 mg/l.

Considering the area's climate, the expected significant reservoir level drawdown, and the low levels of soil nitrate and phosphorus, eutrophication in the proposed Munda Dam reservoir will be unlikely.

Water analysis for the dam site showed that the pH ranges between 8.00 and 8.18. The dissolved oxygen values were found to vary from 4.15 mg/l to 4.30 mg/l. Chloride contents range from 10.59 mg/l to 13.86 mg/l, and the nitrite contents from 0.50 mg/l to 0.90 mg/l. The nitrate contents were found to be between 0.55 mg/l and 1.35 mg/l. Similarly, phosphorus contents were found to be between 1.20 mg/l and 2.40 mg/l.

The values of all these parameters are well within the limits allowed for agriculture. The water is therefore suitable for the cultivation of agricultural crops. Exhibit 4.6 presents the results of water quality analyses.

5. Conclusions and Recommendations

5.1 Conclusions

5.1.1 Flora and Fauna

This ecological survey revealed that the study area's flora and fauna have been significantly affected by human activities. Vegetation communities have undergone significant degradation because of such activities as clearing, fodder collection, livestock grazing, and timber extraction. It is believed that the loss of vegetation due to the construction of the dam and reservoir will not significantly reduce plant biodiversity.

Wildlife communities depend directly or indirectly on the plant communities for habitation. Because the study area's vegetation communities have suffered considerably, the wildlife communities have also been adversely affected. Uncontrolled hunting has also depleted these species greatly. Although some rare and threatened animal species are believed to exist in the area, there have been no sightings of these animals close to the proposed dam, reservoir or command area for many years.

Since plant and animal communities in the study area have already suffered heavily due to the area's human population, the construction of the dam and reservoir, additional irrigation canals, and expansion of the irrigated areas downstream of the dam are not expected to impact negatively on the environment. The expected impacts of the project are summarized in Exhibit 5.1.

5.1.2 Surface and Groundwater Hydrology

The construction of Munda Dam will change the study area's surface water hydrology considerably. The Swat River's flow regime will no longer vary naturally, but will be controlled to maximize electricity generation and agricultural benefits.

These changes in the local hydrology will have significant negative impacts on the aquatic ecology. These are covered in detail in the Munda Dam fisheries report, which has been produced by HBP during this environmental survey.

The groundwater level around the dam and reservoir is expected to rise as a result of the water impounded in the reservoir. However, given the study area's steep topography and good drainage, water logging is not expected to become a problem.

5.1.3 Soils and Water Quality

Soils in the study area were found to be non-saline and non-sodic. Therefore, the expanded irrigation network is not expected to cause salinity or sodicity. The overall land productivity in the area is expected to increase because of increased availability of irrigation water.

Results of the water quality analysis showed that water in the Swat River has low nitrate and phosphate levels. This, combined with the area's climate, and the reservoir's expected drawdown, will prevent eutrophication.

Impoundment of the water and accumulation of waste in the reservoir is expected to deteriorate the reservoir water quality. However, given the area's small population, and the reservoir's large storage volume, the change is not expected to be very significant, and should not pose a threat to public health or to aquatic ecology.

Downstream of the dam site, however, river water quality could deteriorate significantly because the human population in the command area is expected to increase and more waste will then be washed into the river. It is possible that the reduced flow downstream of the dam site will not be enough to adequately dilute and wash away the waste, and the poor water quality could become a hazard for public health and aquatic ecology. A minimum flow of water from the reservoir will have to be maintained at all times.

5.2 Recommendations

Outlined below are some measures for conserving the study area's plant and animal communities. The measures will be sustainable because, in addition to ecological benefits, they will also facilitate the area's socioeconomic uplift.

5.2.1 Wildlife Conservation

The study area could be declared a protected area on the basis of its potential as wildlife habitat for native fauna. A policy preventing cutting of trees, hunting and shooting of the wildlife will have to be strictly enforced. For proper protection and conservation of animals, wildlife conservation societies could be established among the local communities.

5.2.2 Erosion Control

The study area has been damaged greatly by soil erosion. The following methods should be employed to control excessive surface runoff and erosion:

- Construction of diversion channels and check dams
- Construction of proper terraces and contour furrows
- Promotion of contour plowing, followed by protective mulching
- Rangeland management to prevent overgrazing
- Discouragement of the burning of vegetation
- Use of brush paving and wire check dams in gully channels to collect silt and moisture in the gullies, creating conditions favorable for agriculture
- Use of brush, litter, and straw mulches to protect soil
- Establishment of plantations by setting up nurseries at Totakan and near the Bajaur bridge
- Discouragement of vegetation cutting, particularly the *Dodonaea viscosa* (*Sanatha*), which is sold in the Totakan markets.

5.2.3 Construction of Sewerage Systems

Water quality degradation can be prevented by constructing proper drainage and sewerage systems in villages close to the river. Currently, waste from these villages is washed directly into the river. The construction of proper drainage and sewerage systems would enable the proper treatment of village waste before it is released into the reservoir and river, and would reduce the level of water contamination.

5.2.4 Tourism

The project area can be developed and promoted as a potential tourist attraction. The Tourism Department could set up camping grounds or other accommodation facilities for visitors, and the Munda reservoir could be used for activities such as boating, swimming, and fishing.

5.2.5 Social Forestry

The vegetation on mountain slopes in the study area is highly degraded due to overgrazing and woodcutting. Therefore, a large-scale habitat rehabilitation and forestation program, similar to the Malakand Social Forestry Project, should be developed.

Barren areas could be replanted with a combination of fast growing plant species (such as the *Eucalyptus camaldulensis*, *Ailanthus altissima*, and *Robinia pseudoacacia*), and slower growing native species, such as different varieties of pine. The fast growing plants would help reduce soil erosion and provide fodder and fuel wood for farmers; meanwhile, the native, endemic plants would be able to grow and gradually replace the introduced varieties. Over time, given adequate protection, the vegetation in the area could return to its original condition, and wildlife species associated with the native vegetation may return to the area.

The small patches of original plant communities that still remain in the project area need special attention. These contain very small populations of indigenous plant species and are spread over a limited area. According to the ecological studies carried out during the present environmental survey, there are some old and mature plant specimens but, because of heavy livestock grazing and cutting, regeneration species is low. Local villages that have grazing rights in these area should be involved in protecting these communities. These communities should be fenced off to allow the natural vegetation to regenerate.

Since the restoration of natural ecosystems takes a long time, it is necessary to help local people find alternatives to meet their requirements of fuel wood and fodder. An intensive social forestry program could be implemented during which fast growing tree species are cultivated around villages. This would relieve pressure on natural forests, which have already deteriorated to unsustainable levels.

A large-scale forestation program would also significantly reduce siltation of the reservoir, and would increase the life of the dam and reservoir.

5.2.6 Range Management

Range management through the introduction of palatable grasses such as *Chrycopogon aucheri, Andropogon squarosus, Eulaliopsis binata (Babargrass), Saccharum spontaneum (Kai), Cymbopogon jwarancusa, Bromus tectorum (Brom grass), Cenchrus ciliaris, Themeda anathera,* and *Aristida depressa* would help reduce erosion in the area. It would also provide suitable habitat for game birds such as the *chukor*, partridges, pigeons and doves. Reseeding, manuring, and the introduction of good quality grasses would increase the diversity and abundance of wildlife. Local communities should be involved in initiating this program.

5.2.7 Medicinal Plants

The areas that have medicinal plants used by the local communities, such as *Withania coagulans, Cocculus laeba, Artimisia maritima, Ephedra gerardiana, Solanum xanthocarpum* could be protected from overgrazing and vegetation clearing.

Exhibit 2.1: Rare Birds in the Study Area

Species	*Family*
Gypaetus barbatus	Accipitridae
Hieraaetus fasciatus	Accipitridae
Falco columbarius	Falconidae
Falco cherrug	Falconidae
Falco peregrinus	Falconidae
Falco pelegrinoides	Falconidae
Alauda arvensis	Alaudidae

Exhibit 2.2: Threatened Mammals in the Study Area

Species	*Family*
Ovis vignei	Bovidae
Macaca meltada	Cercopithacidae
Capra falconeri magaceros	Bovidae
Panthera pardus	Felidae

Exhibit 2.3: Rare Mammals in the Study Area

Species	*Family*
Hemiechimus collaris	Erinaceidae
Sorex thibetanus	Soricidae
Suncus etruscus	Soricidae
Nyctalus noctula	Vespertilionidae
Pipistrellus javanicus babu	Vespertilionidae
Felis caracal	Felidae
Capra falconeri magaceros	Bovidae

Exhibit 2.4: Rare Reptiles in the Study Area

Species	*Common Name*
Eublepharus macularius	Fat-tailed Gecko
Ablepharus grayanus	Earless Skink
Scineella himalayanum	Himalayan Ground Skink
Varanus bengalensis	Indian Monitor Lizard
Coluber rhodorachius	Cliff Racer
Coluber ravergieri	Mountain Racer
Sphalerosophis diadema schirazianus	Persian Diadem Snake
Ptyas mucosus	Dhaman or Rat Snake
Eirenis persica	Dark Headed Dwarf Racer
Xenochrophis piscater	Checkered Keelback
Sungarus caeruleus	Indian Krait
Naja naja oxiana	Oxus Cobra

Exhibit 2.5: Rare Amphibians in the Study Area

Species	*Common Name*
Bufo viridis	European Green Toad
Rana cyanophlyctis	Skittering Frog

Exhibit 4.1: Details of Soil Samples

ID	Depth (cm)	Location
1	60-90	Village Spina Khawara (Left bank of command area)
2	20-40	Village Janaka (Left bank of command area)
3	11-75	Dew Dheri (Left bank of command area)
4	20-60	Village Spinhai (Left bank of command area)
5	0-20	Village Janaka (Left bank of command area)
6	0-20	Village Surshaheed (Left bank of command area)
7	60-90	Village Daryab Koroona (Right bank of command area)
8	0-20	Right bank of command area
9	20-50	Right bank of command area
10	0-25	Right bank of command area

Exhibit 4.2: Soil Analysis Report

Parameter	Analytical Method	Unit	Analysis Results									
			1	2	3	4	5	6	7	8	9	10
pH	CNSC[a]		7.02	6.91	6.55	6.51	6.90	6.30	7.28	7.11	7.31	6.67
Organic Matter	CNSC	%	0.41	0.66	0.83	0.74	0.80	0.46	0.26	0.35	0.25	0.72
Organic Carbon	CNSC	%	0.23	0.37	0.47	0.42	0.45	0.26	0.14	0.20	0.14	0.41
Nitrate	Hannah[b]	mg/kg	13.0	14.20	15.0	14.1	13.20	14.44	13.12	13.50	14.2	14.4
Nitrogen (Kj)	CNSC	mg/kg	0.19	0.20	0.25	0.30	0.32	0.18	0.12	0.16	0.12	0.30
Phosphorus	Shelton[c]	mg/kg	3.20	3.56	3.60	3.50	3.70	3.80	1.20	3.25	3.20	3.56
Nitrate		mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc		mg/kg	0.5	0.60	0.72	0.66	0.72	0.65	0.65	0.80	0.72	0.78

a Keague, JA, 1978, *Manual of Soil Sampling and Analysis*, Canadian Society of Soil Science
b Kamphake, LJ, Hannah, SA, and Cohen, JM, 1967, *Automated Analysis for Nitrate by Hydrazine Reduction*
c Shelton WR and Harper HJ, 1941, *A Rapid Method for Determination of T Phosphorus in soil and plant*

Exhibit 4.3: Crop Suitability Ratings under Potential Conditions

Soil	Limitation	Land Class	Extent		Suitability Rating[a]									
			Acres	%age	Wheat	Sugarcane	Sugarbeet	Maize	Tobacco	Oil-seeds	Pulses	Fodder	Vegetables	Orchards
Level, deep loamy clayey soils	None	I	13,815	29.3	1	1	1	1	1	1	1	1	1	1
Nearly level, shallow gravelly soils (50 to 60%) at 35 cm and below to 150 cm depth	Shallow depth Gravely nature	IIs	7,350	15.6	2	3	2	3	2	2	2	3	2	3
Undulating, deep loamy soils gently undulating, gravelly loamy soils (20 to 30% gravels on surface, 50% in sub soils)	Undulating graphy	IIr	4,790	10.2	1	1	1	1	1	1	1	1	1	1
	Irregular topography	IIIsr	3,935	8.3	2	3	2	3	2	2	2	3	2	3
	Gravely nature				1	1	1	1	1	1	1	1	1	1
Sloping deep loamy soils with 20 to 30% gravels on the surface	-Irregular graphy													
	-gravelly surface	IIsr	660	1.4										
Excessively gravelly and stony ridges (80 to 90% gravels and stones)	-Very high relief													
	-Excessive gravelly nature													
		IVsr	12,730	27.0	4	4	4	4	4	4	4	4	4	4
Miscellaneous Area	-Non-soil	Not classified	3,880	8.2	4	4	4	4	4	4	4	4	4	4

a 1 Well-suited
2 Moderately suited
3 Poorly suited
4 Not suited

Exhibit 4.4: Command-Wise Statistics of Land Capability Classes

Land Capability Class	Left Bank Command		Right Bank Command		Total	
	Acres	%	Acres	%	Acres	%
I	5455	16.4	8360	60.6	13815	29.3
Iir	4790	14.3	0	0.0	4790	10.2
Iisr	660	2.0	0	0.0	660	1.4
IIIs	4010	12.1	3340	24.2	7350	15.6
IIIsr	3620	10.8	315	2.3	3935	8.3
IVsr	12730	38.1	0	0.0	12730	27.0
Miscellaneous Areas	2100	6.3	1780	12.9	3880	8.2
Total	33365	100.0	13795	100.0	47160	100.0

Exhibit 4.5: Water Sample Details

Lab ID	Description of Location
Reservoir Area	
1	Reservoir area
2	Swat River (Mastosar bridge)
3	Punjkora River
4	Reservoir area
5	Site of confluence
Dam Area	
6	Swat River (Totakan)
7	Mara dab
8	Comp site
9	Down camp site
10	Before Munda barrage
11	After Munda barrage
12	Abazai River (FC post)
13	Khiali River near Tangi

Exhibit 4.6: Water Analysis Report

Sample ID	pH Value	Dissolved Oxygen (mg/l)	Chloride (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)	T-Phosphate (mg/l)
1	8.35	3.50	11.41	0.06	1.10	1.20
2	8.35	3.50	11.41	0.06	0.85	1.20
3	8.38	3.80	11.41	0.06	0.80	1.30
4	8.44	3.40	9.78	0.05	0.95	0.65
5	8.25	4.0	17.93	0.07	0.70	1.80
6	8.20	4.0	17.93	0.07	0.70	1.85
7	8.15	4.20	10.59	0.80	1.0	2.0
8	8.15	4.25	10.59	0.85	0.55	2.10
9	8.16	4.15	10.59	0.80	0.55	2.40
10	8.14	4.30	13.86	0.75	0.80	1.50
11	8.14	4.20	13.86	0.50	1.35	1.20
12	8.15	4.20	13.86	0.90	1.30	2.10
13	8.18	4.20	13.86	0.85	1.30	1.50

Analysis performed at environmental laboratory of Hagler Bailly Pakistan, Islamabad.

Exhibit 5.1: Potential Environmental Impacts

Component	*Environmental Issue*	*Impact*
Physical		
Water	Siltation of reservoir	Long-term negative
	Reservoir and river water quality	Negative
	Discharge downstream of dam	Negative
	Irrigation water quality	Positive
	Groundwater quality	-
	Groundwater level (water logging)	Negative
	Flooding	Positive
Land	Soil salinity	-
	Soil alkalinity	-
	Soil erosion	-
	Land availability	Positive
	Land capability	Positive
Atmosphere	Dust	Negative (construction)
	Odor	-
	Noise	Negative (construction)
Climate	Climate change	-
	Micro-climate change	Negative
Biological		
Fauna	Bird communities / habitats	Positive
	Mammal communities / habitats	Negative
	Reptile communities / habitats	Negative
Flora	Forests / trees	Negative
	Scrub vegetation in gorge	Negative

Exhibit 5.2: Mitigation Measures for Negative Impacts

Impact	*Mitigation Measure(s)*
Siltation of reservoir	Implementation of a watershed management program.
Reservoir and river water quality degradation	Construction of sewerage systems for villages close to the reservoir / river. Releasing adequate compensatory water downstream of the dam.
Inadequate discharge downstream of dam	Releasing adequate compensatory water downstream of the dam.
Increase in groundwater level (water logging)	None required.
Dust	Sprinkling water around construction areas and access tracks.
Noise	Insulating machinery. Locating machinery away from settlements.
Micro-climate change	None required.
Destruction of mammal communities / habitats	Declaring the area as a protected area and controlling hunting and habitat destruction.
Destruction of reptile communities / habitats	Declaring the area as a protected area and controlling hunting and habitat destruction.
Destruction of forests / trees	Implementing a social forestry program.
Destruction of scrub vegetation in gorge	Implementing a rangeland management program.

Appendix A: Photographs

ExhibitA.1: *Dodonea* Encroaching on a Degraded *Olea* Community

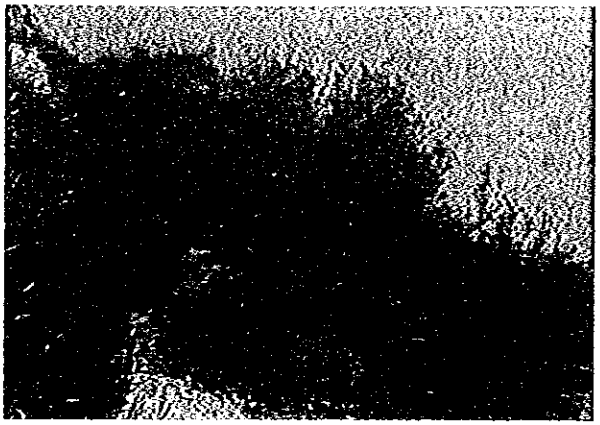

Exhibit A.2: A Community with Beri, Kikar, and Mazri Plants Near the Dam Site

Exhibit A.3: A Community with *Acacia, Zizyphus* and *Adhatoda* Near the Dam Site

Exhibit A.4: *Acacia nilotica* Community

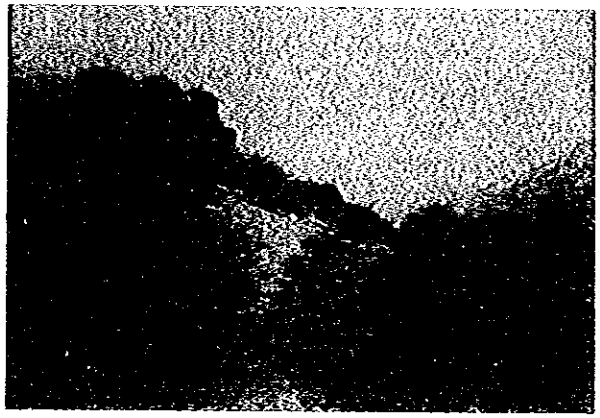

Exhibit A.5: Highly Degraded Area with a few *Rhazya stricta* Plants

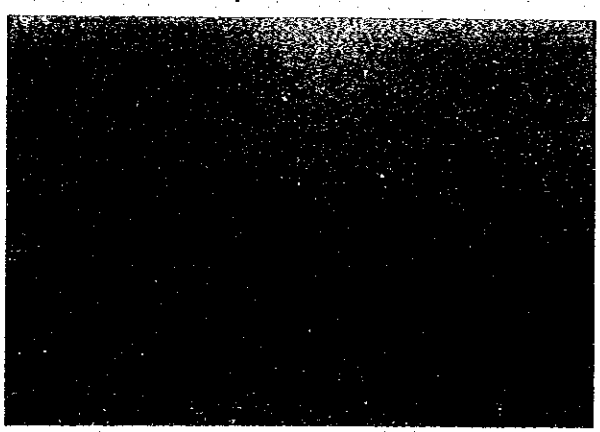

Exhibit A.6: Munda Headworks with *Acacia* Plantation in the Background

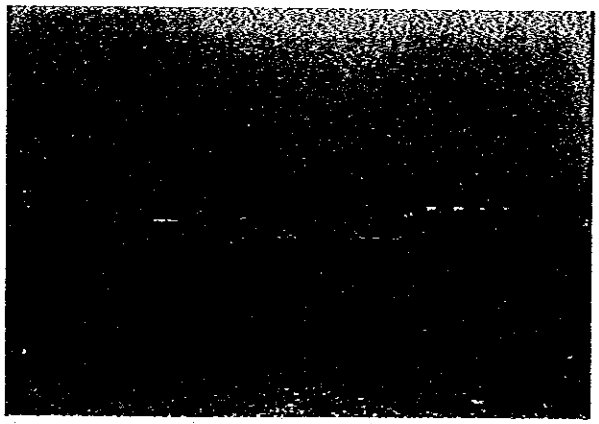

Exhibit A.7: Fast-growing Species should be planted in such Barren Areas around Settlements

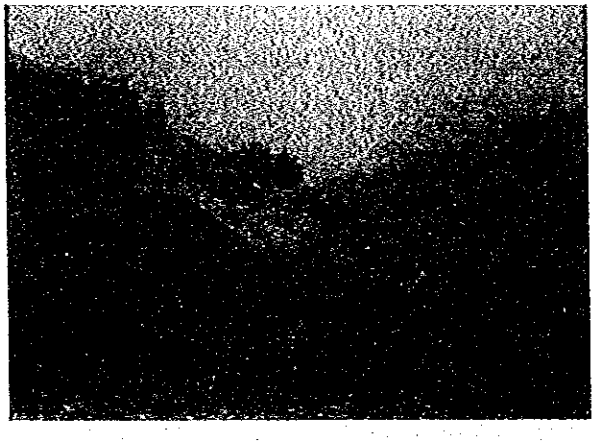

Exhibit A.6: Munda Headworks with *Acacia* Plantation in the Background

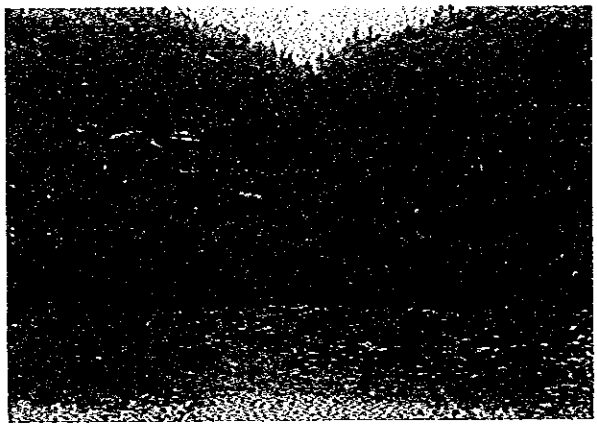

Exhibit A.9: *Morus* (mulberry) and *Acacia* Plantation near Reservoir Area

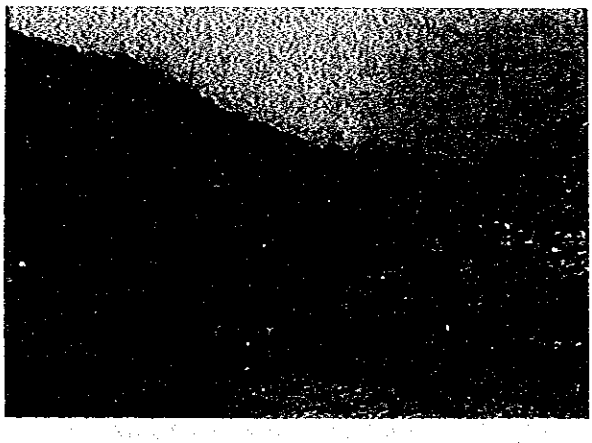

Exhibit A.10: Degraded Area with Scattered *Olea* and *Monothica* Plants

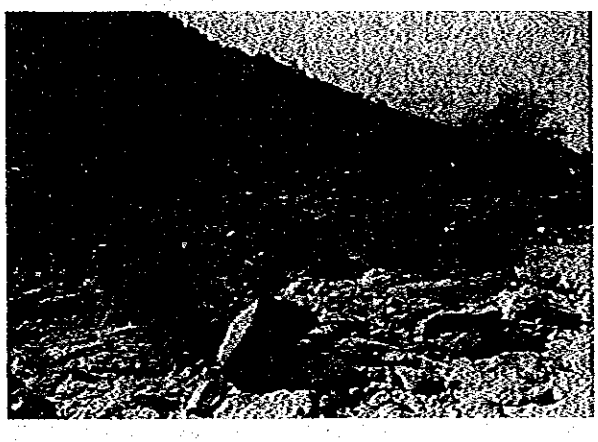

Exhibit A.11: Area near Confluence of Swat and Pinjkora Rivers

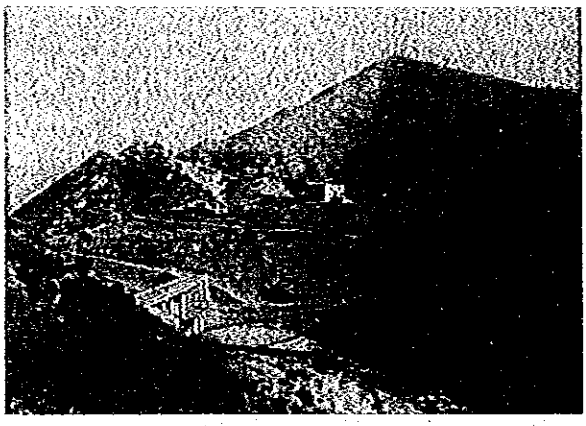

Exhibit A.12: Scattered *Acacia nilotica* Trees in Highly Degraded Area near Dam Site

Exhibit A.13: Degraded Area Covered with *Adhatoda* Plants

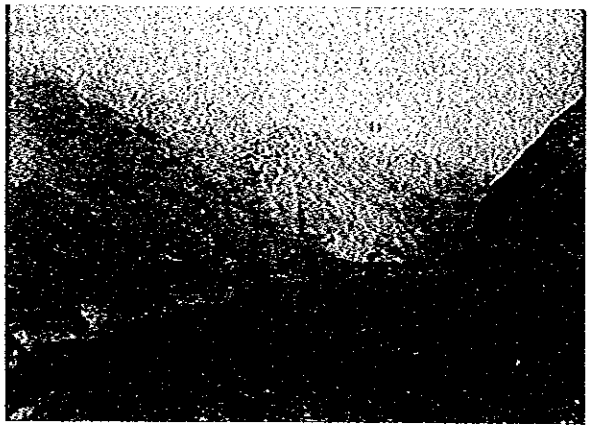

Exhibit A.14: Small *Acacia modesta* patch on a largly degraded slope

Exhibit A.15: Ideal Site for Plantation of Fast-growing Fodder and Firewood Species

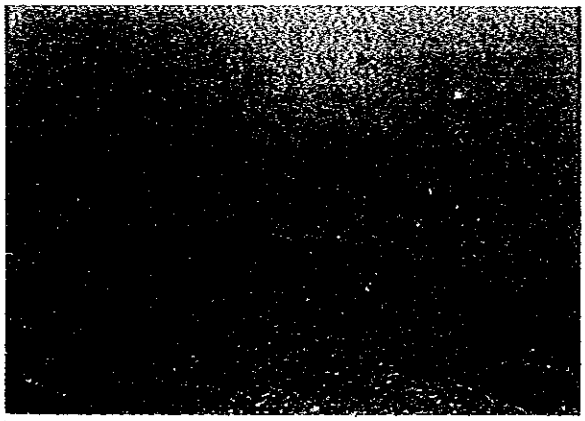

Exhibit A.16: Cows Grazing in a Degraded *Acacia nilotica* Community

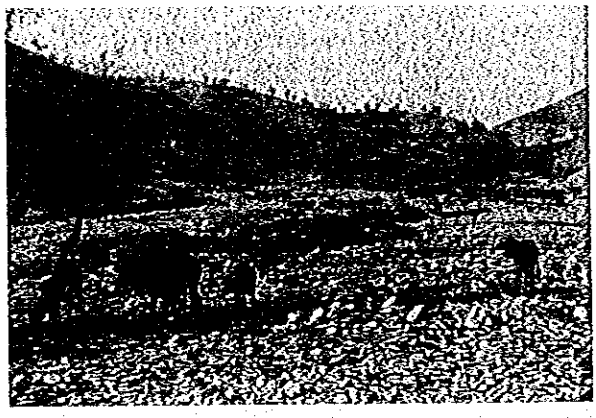

Exhibit A.17: A Cow Feeding on Tough, Unpalatable, Grass

Exhibit A.18: Highly Degraded Slope at the Munda Dam Site